The Workshop on Low-Carbon Fuel Standards

TAKING STOCK OF THE IMPLICATIONS AND ASSESSING THE FUTURE OF LCFS IN BRITISH COLUMBIA

FINAL REPORT | JUNE 2013

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About the Report

This report was prepared by Pollution Probe to relay subject matter expert and key stakeholder discussion on the current state of Low-Carbon Fuel Standards (LCFS) regulations in Canada, United States and Europe that occurred during the *Workshop on Low-Carbon Fuel Standards: Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia*. The workshop was held on October 12th and 13th, 2011, in Victoria, British Columbia. The report captures perspectives shared by the workshop presenters and the participants and provides recommendations for advancement of the LCFS regulations. In this report, Pollution Probe endeavoured to summarize the speakers' presentations, and the discussions that ensued, in a fair and accurate manner, to the best of its ability. The recommendations do not represent consensus viewpoints among workshop participants; rather, the recommendations solely represent Pollution Probe's advice, based on its observations and findings emerging from the workshop.

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Disclaimer

The contents of this report reflect discussions that took place during the *Workshop on Low-Carbon Fuel Standards: Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia*, which was held on October 12th and 13th, 2011, in Victoria, British Columbia. This report is published for informational purposes and should in no way be considered to represent the official position of the supporting organizations or the workshop participants.

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About Pollution Probe

POLLUTION PROBE has been effectively promoting policies and programs to improve the environmental performance of transportation systems in Canada for 20 years. Our goal has been to reduce emissions from vehicles that pollute the air and contribute to climate change.

Our contributions to clean transportation in Canada:

Since 1993, Pollution Probe has run the Clean Air Commute™ – an annual public awareness campaign that has engaged more than 700 workplaces in the Greater Toronto Area to encourage more than 100,000 employees to use more environmentally sustainable means of commuting for one week in June. This program has helped many commuters to permanently switch to cleaner modes of transportation and has kept thousands of tonnes of pollutants out of the air. In 2001, Pollution Probe initiated the S.M.A.R.T. Movement Programme (Save Money and Air by Reducing Trips), which helped employers to establish progressive commuting policies year-round and led to the establishment of the Smart Commute Association. Pollution Probe is also a strong voice in favour of multi-level government support for public transit in urban areas.

Pollution Probe was instrumental in the passage of Ontario legislation in the late-1990s, leading to the establishment of the Drive Clean program. In the early years of the following decade, the organization played an important role in supporting stringent sulphur-in-fuel regulations, which paved the way for tighter air pollutant emissions standards for light- and heavy-duty vehicles.

In 2004, Pollution Probe began significant work on finding ways to improve the fuel efficiency of new automobiles – a major source of greenhouse gas emissions in Canada. During the years that followed, Pollution Probe produced a series of major reports detailing the technological opportunities for improvement and the economic and social implications of reducing fuel consumption, as well as profiling the barriers to market adoption of fuel-saving vehicle technologies. Pollution Probe engaged an international array of experts to inform its research and advocacy, and consulted with industry extensively. This work helped build momentum toward government action, in which Pollution Probe's policy recommendations were heeded. In 2007, the federal government committed to regulate fuel consumption levels in new automobiles and, in 2010, it published draft regulations to limit greenhouse gas emissions from all new light-duty vehicles, beginning with the 2011 model year. This represented the first regulatory action in Canada to directly control greenhouse gas emissions across the country.

The expertise and capacity that Pollution Probe built through this process led to its involvement in several important transportation initiatives and partnerships. In 2008, Pollution Probe became a member of the steering committee that drafted Canada's Electric Vehicle Technology Roadmap – an industry-led and federal government-supported initiative. Pollution Probe's partnership with the Canadian Automobile Association produced valuable education and outreach materials, including the *Primer on Automobile Fuel Efficiency and Emissions*. Pollution Probe also researched and wrote a major report on industrial freight transportation, published by Sustainable Development Technology Canada in 2009, and advised the Secretariat of the Commission for Environmental Cooperation in the development of its recommendations for a North American integrated sustainable freight transportation strategy, published in 2011. That same year, Pollution Probe project-managed Canada's first residential customer electric vehicle and charging station deployment project, called the *Toronto Hydro smart Experience*: a collaborative initiative of Toronto Hydro Electric System Limited and smart Canada (a division of Mercedes-Benz Canada).

POLLUTION PROBE REPORTS AND PUBLICATIONS ON TRANSPORTATION-RELATED TOPICS:

- Driving Electric: Understanding Electric Vehicle Technology and Environmental Benefits (September 2011)
- Unlocking the Electric Mobility Potential of Toronto: Moving Toward an Electric Mobility Master Plan for the City (October 2010)
- Sustainable Development Business Case™ Report on: Industrial Freight Transportation (November 2009)
- Primer on Automobile Fuel Efficiency and Emissions (produced in partnership with the Canadian Automobile Association, November 2009)
- Promoting and Sustaining Consumer Demand for Highly Fuel Efficient Automobiles: A "How-To" Guidebook Developed by Pollution Probe (produced in partnership with the Canadian Automobile Association—South Central Ontario, June 2009)
- Purchasing Fuel Efficient Vehicles in Canada (produced with the Centre for Excellence in Public Sector Marketing, June 2009)
- Public Opinion Research: Purchasing Fuel-Efficient Vehicles in Canada (June 2009)
- Canadian's Perceptions of Electric Vehicle Technology: A National Consumer Research Project (March 2009)
- Low-Carbon Fuel Standards for Canada (2009)
- Vehicle Fuel Efficiency Ranking and Labelling: A Report of the Pollution Probe Workshop to Scope Systems for Identifying and Labelling Light-Duty Vehicles according to Fuel Efficiency and Emissions Performance (2008)
- Environmental Non-Government Organization Delegate Consolidated Report on the Development of Canada's Motor Vehicle Fuel Consumption Regulations (2008)
- A Strong Canadian Auto Industry in a Fuel Efficient Future: A Commentary on Automotive Industry Policy in the Context of Climate Change, Vehicle Fuel Efficiency Regulations and Carbon-Constrained Markets (2007)
- A Global Survey of Highly Fuel Efficient, Low Greenhouse Gas Emitting Vehicles (2007)
- Driving Towards a Cleaner Environment—A Healthier Future (produced in partnership with the Canadian Automobile Association, 2006)
- Complementary Measures: A Report of the Pollution Probe Workshop to Scope Measures that Promote and Encourage Consumer Demand for More Fuel Efficient Vehicles (2005)
- Greenhouse Gas Emissions and Vehicle Fuel Efficiency Standards for Canada (2005)
- Moving Together Towards a Healthier and More Sustainable Future: A Report from the Transportation, Air Issues and Human Health Conference (produced in partnership with the York Centre for Applied Sustainability 2004)
- S.M.A.R.T Movement: Saving Money and the Air by Reducing Trips (2001)

Executive Summary

Many measures aimed at reducing transportation sector greenhouse gas (GHG) emissions have been introduced by policymakers around the world. For the most part, these measures have focused on changing driver behaviour, on promoting vehicle technologies that increase energy efficiency and on reducing reliance on personal vehicle use. Usually, the direct impacts of these measures are borne by transportation energy end-users (i.e., consumers) and manufacturers and importers of vehicles. This seems a reasonable focus given that more than 75 per cent of the GHG emissions associated with the transportation sector are a result of the combustion of fuels in vehicles' engines. Recently, policymakers have begun to consider regulations on the *carbon intensity* (CI) of transportation fuels, aiming to reduce GHG emissions associated with the production, refining and delivery of fuels. A Low-Carbon Fuel Standard (LCFS) regulation is one of such measures intended to reduce, on a fuel lifecycle basis, the CI of transportation fuels.

Pioneered in California, the LCFS is based on a lifecycle approach, which measures GHG emissions per unit of energy associated with each of the steps in the fuel lifecycle – from production to use, or from "well-to-wheel" for fossil fuels and "seed-to-wheel" for biofuels.[1]

In Canada, the provinces of British Columbia (BC) and Ontario have signed a Memorandum of Understanding with California to match the state's commitment to reduce transportation fuel lifecycle emissions by 10 per cent by 2020 compared to the 2010 baseline. Whereas no significant progress has been made to advance the LCFS in Ontario, BC's Ministry of Energy and Mines introduced the *Renewable and Low Carbon Fuel Requirements Regulation* (RLCFRR) on January 1st, 2010.

Pollution Probe organized the *Workshop on Low-Carbon Fuel Standards: Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia* to discuss the RLCFRR in the context of lessons learned from other jurisdictions that have implemented LCFS-based regulations, to assess the options for compliance with CI limits under the RLCFRR and to gain perspectives on emerging fuel and vehicle system technologies that may facilitate compliance, as well as on other policy alternatives to reduce transportation sector emissions,. The workshop was attended by key subject matter experts from government and non-governmental organizations, and key industry stakeholders.

The goal of this report is to reflect the candid discussion that took place during the workshop, to flag key concerns expressed about the regulation and to highlight policy opportunities for mitigating transportation sector greenhouse gas emissions more effectively. It seemed evident to all present that the LCFS is intended to bring about a transformation of the energy system that powers transportation services, from one that is currently served by fuels derived from oil – a fossil fuel – to a system that is powered by a diverse range of alternatives, such advanced biofuels, natural gas and electricity – preferably derived from renewable energy sources that contribute few GHG emissions to the atmosphere.

However, it was noted by many workshop participants that to complement this diverse range of fuel options, a corresponding transformation of vehicle technology and supporting energy infrastructure is required. For example, if electricity were to supplant gasoline as the dominant vehicle "fuel", electric motors, advanced batteries and electric vehicle charging infrastructure would be needed to displace internal combustion engines, petroleum product distribution systems and retail pumping stations. The implications of LCFS may prove to be far-reaching, requiring a much more ambitious scale of transformation than contemplated under traditional regulatory measures, such as standardizing fuel composition or requiring the blending of ethanol in gasoline.

1 Under the LCFS, "regulated parties", which are usually fuel producers and suppliers, are required to quantify the average lifecycle carbon intensity of their transportation fuels, pooled for sale in a given market, and meet each year's specified carbon intensity limits. These limits are incrementally lowered every year to promote a more diverse spectrum of fuel alternatives and changes in vehicle powertrain technology. The regulated parties can engage in credit trading to meet the carbon intensity limits by acquiring credits for fuels with carbon intensity levels below the annual carbon intensity limits.

A question that emerged from the workshop dialogue was whether the transformation of the transportation energy system envisioned under the LCFS could actually be carried by regulation as the sole instrument of government policy – and whether it was the right tool in the first place for the task. To this point, no clearly articulated pathway to compliance with the RLCFRR targets in 2020 was submitted for debate throughout the workshop.

Several presenters noted that, of the total GHG emissions produced over the lifecycle of a petroleum fuel, less than one-third originates "upstream" of the vehicle – the rest are generated "downstream", in the combustion of the fuel in vehicle engines. Therefore, to comply with the 10 per cent reduction target on lifecycle emissions intensity, the petroleum companies are faced with achieving a one-third reduction in the GHG emissions associated with the production and shipping of their product to market. While some sector representatives indicated that marginal process efficiencies may be discovered, achieving additional energy savings of one-third in the refinery and delivery business is technically infeasible.

Thus, regardless of how efficiently the extraction of oil and its refining into gasoline or diesel is conducted, the regulated targets for CI are not achievable unless fuel suppliers displace these conventional fuels with less carbon-intense alternatives. Many workshop participants remarked that the regulation, therefore, requires petroleum companies to become producers and brokers of non-petroleum based transportation energy products, which some considered to be economically impracticable and an unfair use of regulatory instruments. Others, by contrast, believed that a regulatory-driven displacement of gasoline and diesel with fuel alternatives is one of the most effective means to rapidly transform a transportation energy system that is currently incompatible with a vision of deep reductions in GHG emissions by mid-century.

Another dimension of LCFS discussed at the workshop was that compliance does not rely on actual measurement of the CI of fuels supplied to market. Instead, the LCFS relies on lifecycle models to estimate the relative CI of different fuel options. In BC, GHGenius is the model used; in California, GREET is used. These models can produce somewhat different outputs, since they incorporate different input values and boundary conditions, reflective of different assumptions and regional differences in source data, for example. These models are powerful tools for understanding the "climate impact" of different types of fuels, which is crucial for informing policy options. However, some workshop participants expressed concern about whether the models should constitute the basis for regulatory compliance, given that they are constantly evolving.

Building on the range of issues identified throughout the workshop, Pollution Probe sees three distinct options for the BC Government to consider going forward:

1. Stay the course on the RLCFRR but modify aspects of the regulation to address legitimate issues.
2. Shift focus to other GHG abatement efforts.
3. Bridge from RLCFRR as regulation to a more comprehensive strategic framework, inclusive of several complementary policies and measures to reduce emissions from transportation energy use.

For each of these options, Pollution Probe has developed a brief set of recommendations. These recommendations are detailed in Chapter 7, and are summarized as follows:

1. STAY THE COURSE ON THE RLCFRR BUT MODIFY ASPECTS OF THE REGULATION TO ADDRESS LEGITIMATE ISSUES.

- Maintain a renewable fuel content requirement in gasoline and diesel in the 2020 timeframe.
- Establish a single reference case against which progress toward CI compliance is measured.
- Monitor and measure changes in vehicle powertrain efficiency and incorporate them into compliance calculations.
- Consider the evaluation and assignment of credits towards compliance for investments made by obligated parties (and their agents) in low-carbon transportation energy distribution infrastructure and technology in the province.
- Dedicate resources to complementary measures that strongly support the achievement of the RLCFRR compliance among fuel suppliers, such as investments in low-carbon fuel alternatives, advanced technology Research, Development and Commercialization (RD&C) and enabling fuel storage and distribution infrastructure.
- Consider changes to the CI reduction targets or the timeframes that would align with identified compliance pathways, and with applicable compliance flexibilities under the RLCFRR.

2. SHIFT FOCUS TO OTHER GHG ABATEMENT EFFORTS.

- Maintain a renewable fuel content requirement in the gasoline and diesel pool.
- Investigate the potential comparative advantages to the end-user of using alternative fuels and advanced technology vehicles and, where possible, means of enhancing their value proposition to the market.
- Consider financial incentives that accelerate market uptake of highly fuel efficient vehicle models and advanced fuel saving technologies.
- Make industrial freight transportation a priority of the government in terms of reducing fuel consumption and GHG emissions.
- Utilize the price signal inferred through BC's carbon tax by aligning it with the CI of fuels sold in the province.

3. BRIDGE FROM RLCFRR AS REGULATION TO A MORE COMPREHENSIVE STRATEGIC FRAMEWORK, INCLUSIVE OF SEVERAL COMPLEMENTARY POLICIES AND MEASURES TO REDUCE EMISSIONS FROM TRANSPORTATION ENERGY USE.

- The Government of British Columbia should take the lead in developing a national vision and strategy on the sustainability of transportation energy use in Canada, for which the provinces, the federal government and industry each have specific responsibilities.

A General Recommendation

Regardless of the way forward chosen by the Government of British Columbia, it will require increased capacity through external collaborations, expert input on a wide array of subjects ranging from technology and fuels to economics and policymaking, and advice from individuals and organizations throughout the transportation energy value chain, and from centres of academia. Therefore, Pollution Probe strongly recommends that a special Advisory Group be established, complete with terms of reference and accountabilities, to support the BC Government in the execution of its mandate to develop a more sustainable transportation system for the benefit of its citizens.

Pollution Probe also submitted a set of Guiding Principles for the BC Government to keep in mind as it further develops the RLCFRR:

- Net global reductions in GHG emissions should be an outcome of a well-designed and implemented policy framework to address climate change.
- Sustainability should not be sacrificed in the pursuit of GHG emissions reductions.
- Clarity on the role of government is necessary at the outset.
- Evaluation and continuous improvement are important commitments, particularly considering the innovative nature of the RLCFRR and its relatively recent introduction.
- Transparency regarding the objectives of the RLCFRR in BC is necessary.
- Policy effectiveness is an important tenant to ensure that the correct tool(s) is used to achieve GHG emissions reduction at lowest cost to government, industry and the public. There are two important ways in which this principle should be expressed:
    - Verification of compliance pathways is a critical source of planning for government and industry.
    - Commitment to tangible progress requires that a lack of information is not a rationale for inaction.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

Bbl	Billion barrels
BTU	British Thermal Unit
CARB	California Air Resource Board
CGSB	Canadian General Standard Board
CI	Carbon Intensity
CNG	Compressed Natural Gas
CPPI	Canadian Petroleum Products Institute
BC RFRR	British Columbia's Renewable Fuel Requirement Regulation
E10	10 per cent ethanol and 90 per cent gasoline
E85	85 per cent ethanol and 15 per cent gasoline
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
EU FQD	EU Fuel Quality Directive
EV	Electric Vehicle
FFV	Flexible Fuel Vehicles
GHG	Greenhouse Gas
GGRTA	Greenhouses Gas Reduction Targets Act
GREET	Greenhouse Gas Regulated Emissions and Energy Use in Transportation model
GTAP	Global Trade Analysis Report
HCICO	High Carbon Intensity Crude Oil
HDRD	Hydrogenation Derived Renewable Diesel
HVO	Hydro-treated Vegetable Oil
iLUC	Indirect Land Use Changes
LCFS	Low-Carbon Fuel Standard
LCFRTF	Low-Carbon Framework for Road Transportation Fuel
LCA	Lifecycle Analysis
LNG	Liquefied Natural Gas
NGV	Natural Gas Vehicle
NAFTA	North American Free Trade Agreement
NAAEC	North American Agreement on Environmental Cooperation
RED	Renewable Energy Directive
RFS2	2012 Renewable Fuel Standard Program
RLCFRR	Renewable and Low Carbon Fuel Requirements Regulation
RTFO	Renewable Transport Fuel Obligation
WTW	Well-to-Wheel
WTT	Well-to-Tank
TTW	Tank-to-Wheel
ZEV	Zero Emissions Vehicle

Chapter 1: Introduction

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On October 12th and 13th, 2011, Pollution Probe hosted a *Workshop on Low-Carbon Fuel Standards: Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia* that was held in Victoria, British Columbia (BC). The workshop was organized at the recommendation of BC's Ministry of Energy and Mines to discuss top-priority issues and gain key stakeholder feedback on Low-Carbon Fuel Standard (LCFS) regulations that have emerged in California, BC and other global jurisdictions.

The workshop provided a neutral forum for the exchange of knowledge and perspectives among subject-matter experts and brought together government representatives, fuel and energy product suppliers, energy producers, vehicle powertrain original equipment manufacturers, energy and emissions lifecycle analysis experts, academia, environmental and non-governmental organizations. The workshop consisted of expert-led presentations, question and answer periods and moderator-led breakout sessions (please refer to Appendix A and Appendix B for the detailed agenda and a list of workshop participants, respectively). In particular, the main objectives of the workshop were:

- To review the original intent of LCFS in the US and Canada in the context of global transportation-related emissions, and the process of development of low-carbon transportation fuel regulatory frameworks that followed;
- To take stock of the current low-carbon fuel requirements in BC and the status of LCFS in other jurisdictions, and to consider the lessons learned;
- To identify the environmental and economic impacts of LCFS from the perspectives of government and of industry;
- To evaluate the nature and capabilities of the fuel supply industry in the context of LCFS compliance; and,
- To identify and evaluate emerging fuel and vehicle system technologies, policy options (including alternative compliance pathways and opportunities for harmonization with other jurisdictions or related policies such as renewable fuel mandates), and alternative approaches for addressing transportation-related GHG emissions in the future.

To achieve these objectives, a context-setting plenary discussion and three in-depth parallel sessions commenced on the first day of the workshop: (1) Policymaking and Regulation, (2) Vehicle Fuel System and Powertrain Technologies, (3) Lifecycle Analysis (LCA) and Regulatory Information. The sessions provided an opportunity for workshop participants to assess the LCFS from policy and regulatory perspectives, to learn about vehicle fuel system and powertrain technology options for reducing greenhouse gas emissions and to gain better understanding of the fuel lifecycle analysis methodologies foundational to the LCFS development. After attending the parallel session of interest, the workshop participants reconvened to discuss their learnings and identify topics for a more open-flow discussion during the next day.

The second day of the workshop consisted of three rotation sessions during which the participants identified critical issues arising from the content presented in the plenary sessions and in their respective day one parallel sessions. Moderators provided a brief summary presentation on each topic to set common ground for discussion and then the floor was opened for active knowledge-sharing and brainstorming of the LCFS-related topics.

This report captures perspectives of both presenters and workshop participants as shared during the workshop and provides recommendations for the advancement of the LCFS-related policy based on the most recurring themes raised in the dialogue. The report is organized in alignment with the workshop agenda, with Chapter 2 reflecting the information conveyed during the plenary discussions; Chapter 3, 4 and 5 providing an overview of *Policymaking and Regulation*, *Vehicle Fuel System and Powertrain Technologies* and *Lifecycle Analysis and Regulatory Information* parallel sessions, respectively; and Chapter 6 summarizing workshop participant observations on top-priority issues and suggestions for the RLCFRR implementation, as shared during the second day of the workshop. Building largely on the findings from the second day of the workshop, the report concludes with a set of recommendations to inform future Renewable and Low Carbon Fuel Requirements Regulation (RLCFRR)-related policy advancement in BC.

Chapter 2: Plenary Discussion

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In the developed world, GHG emissions associated with transportation energy use tend to comprise a large share of nations' emissions inventories, sometimes second only to electricity production. As a result, efforts to reduce transportation-related GHG emissions have become a priority for many governments. In Canada, the US and in Europe, policies are being considered and implemented that focus not only on the direct emissions from vehicles, but that also seek to transform the supply of transportation fuels from the current, dominant mix of gasoline and diesel, to a mix that is less carbon-intense. To this end, policies that aim to reduce GHG emissions beginning with the extraction of oil and ending with its use in the vehicle – often called the "lifecycle" of the fuel – are emerging.

The implications of this new approach are far-reaching; much more so than that of other GHG emissions regulations considered to date, which tend to focus on just one element of the fuel lifecycle. Nonetheless, jurisdictions are proceeding with variations of policies focused on the carbon intensity (CI) of fuels, including BC and California in North America, and the United Kingdom in Europe.

Day One of the *Workshop on Low-Carbon Fuel Standards: Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia* opened with a context-setting plenary session of two parts. The purpose of the first part was to broadly orient the participants to the design and structure of the key regulations in place or under development in North America and Europe, comparing and contrasting the different approaches, while delving more deeply into the specifics of the *Renewable and Low Carbon Fuel Requirements Regulation* (RLCFRR) in BC. The purpose of the second part was to hear from the regulated and implicated parties under RLCFRR regulation in BC to better appreciate their perspectives and concerns. Together these sessions were intended to prime the participants for the more detailed discussions in the parallel sessions that followed, and the process of issues identification on Day Two of the workshop.

Pollution Probe was honoured to have BC's Clean Technology Parliamentary Secretary to the Minister of Energy and Mines, MLA for Richmond-Stevenson, John Yap, attend the opening plenary. Secretary Yap provided welcoming remarks to the workshop speakers and participants and shared insights on BC's progress on the RLCFRR.

Secretary Yap began by stating that BC was a leader in efforts to reduce carbon from the transportation sector and will continue to be so. Secretary Yap noted that two of the key steps in advancing the province's RLCFRR efforts were the consultation with industry on how to improve BC's low-carbon fuel requirements and a review of actions that other global leaders are taking to advance low-carbon transportation fuel options. Both the consultation and the review were recently completed and provided for a review by the Minister of Energy and Mines, Honourable Rich Coleman. Changes to the RLCFRR regulation were planned to occur in the early 2012.

Secretary Yap noted that 36 per cent of the province's GHG emissions come from the burning of fossil fuels for the transportation sector. To reduce the GHG emissions in this sector, the province passed the *GHG Reduction (Renewable and Low Carbon Fuels Requirements) Act*, the *Carbon Tax Act* and the *Clean Energy Act* as part of the 2007 Energy Plan and the 2008 Climate Action Plan. RLCFRR, which includes requirements to reduce the CI of transportation fuels by 10 per cent by 2020 compared to a 2010 baseline, was introduced under the *GHG Reduction Act*, and came into force January 1, 2010.

Secretary Yap asserted that achieving reductions from the transportation sector would require investment in lower carbon fuels and infrastructure. Market-based measures, including provisions for carbon credits, were selected as the best means to challenge industry to innovate and invest in new fuels technology and infrastructure while addressing economic and regional competitiveness issues. Secretary Yap underscored the importance of developing new partnerships in order to leverage the knowledge and expertise to develop best practices and to "think outside of the box".

WHAT IS CARBON INTENSITY AND HOW IS IT CALCULATED?

The Low-Carbon Fuel Standards (LCFS) in BC and California rely on two related concepts; namely, **Lifecycle Analysis (LCA)** of greenhouse gas (GHG) emissions and **Carbon Intensity (CI)** of transportation fuels.

LCA refers to a methodology of tracking and quantifying the GHGs that are emitted at each stage of the product lifecycle of a given unit of fuel. For example, gasoline usually begins its lifecycle as crude oil extracted from certain geologic formations in the earth, whereupon it can be transported, upgraded and refined into gasoline, transported again and finally pumped into a vehicle's fuel tank, where it is eventually combusted in the vehicle's engine, producing heat that is harnessed as mechanical energy to power to the vehicle. Throughout this continuum, energy is added to work the product through the phases of its lifecycle (e.g., mechanical energy for extraction, heat energy for refining and transportation energy for shipping). The GHG emissions associated with the use of energy summed over the entire product lifecycle comprises the CI of the fuel. To enable useful comparisons of CI between different fuel options, a common measure of energy (e.g., a megajoule, MJ) is used to normalize the CI, and the GHG emissions are represented in carbon dioxide-equivalent masses, usually expressed in grams, or gCO_2e. Thus, for the purposes of LCFS, the CI of fuels is represented as gCO_2e/MJ.

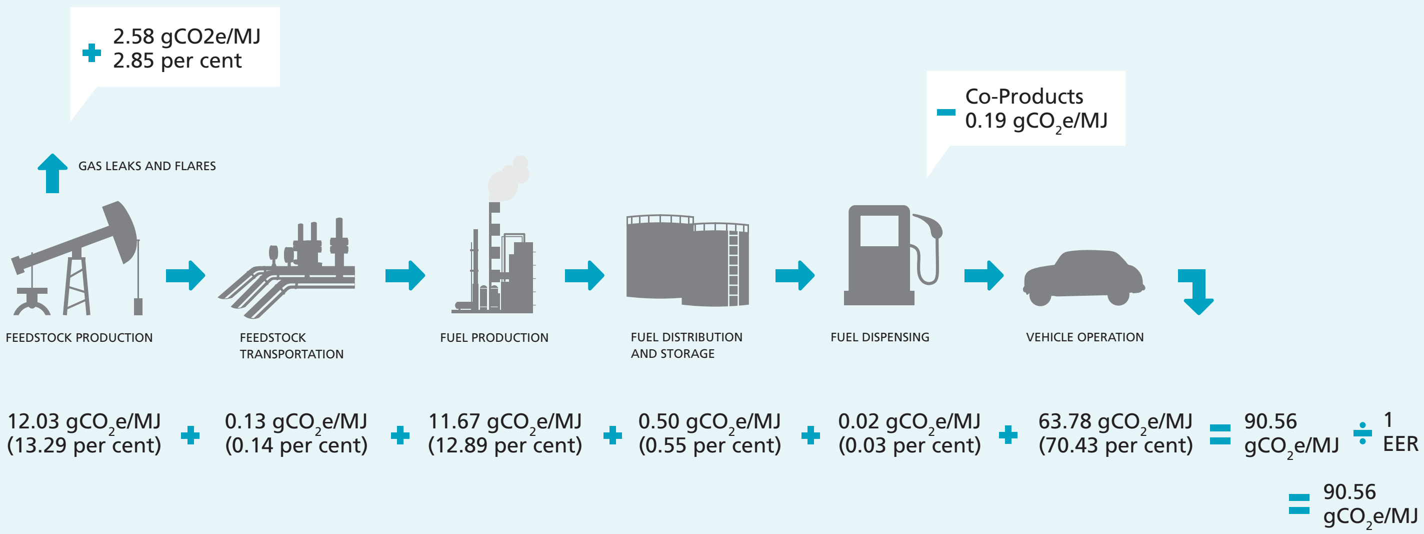
Another concept introduced under the LCFS to account for the contribution of vehicle efficiency to the CI of a given fuel is the **Energy Efficiency Ratio (EER)** of a fuel. The CI of a given fuel can be highly dependent on how efficiently it is converted into energy to power a vehicle. This efficiency is a function of the engine and the transmission, collectively referred to as a vehicle's powertrain. The more efficient the powertrain, the more of the energy potential in the fuel (in the tank) is put to useful work at the wheels of the vehicle. Furthermore, different fuels have different chemical properties, and these properties sometimes determine how efficiently the energy potential in the fuel can be converted by the engine. The interdependency between fuels and powertrain technology is reflected in the LCFS through the use of a non-dimensional factor, called the EER. Each of the fuel options identified in the regulation is associated with a specific EER, by which the CI of the fuel is divided. Thus, the more efficiently the fuel that is supplied to the vehicle can be used, the higher its EER. This, in turn, reduces the CI of the MJ of a fuel, which would otherwise simply represent the sum of gCO_2e emitted at each stage of the fuel's lifecycle from the "well" to the "tank" and the eventual combustion of that fuel. Thus, the application of the EER reflects the useful work performed in the conversion of that MJ of energy as it advances from the "tank" to the "wheels".

The interdependency between fuels and powertrain technology is reflected in the LCFS through the use of a non-dimensional factor, called the EER. Each of the fuel options identified in the regulation is associated with a specific EER, by which the CI of the fuel is divided. Thus, the more efficiently the fuel that is supplied to the vehicle can be used, the higher its EER.

The following three examples, for reformulated gasoline, ethanol and compressed natural gas, demonstrate how different fuel options – also called "pathways" – are assessed and ascribed a CI value under the BC RLCFRR. The stages shown in each fuel's lifecycle were chosen for simplicity, noting that some LCA models may delineate the stages in the product continuum somewhat differently. The EER and CI values (unadjusted) used in these examples are based on the values shown in Appendix C and E of the BC Government's *Low Carbon Fuel Requirements Regulation Intentions Paper for Consultation*.[2]

2 http://www.empr.gov.bc.ca/EEC/Strategy/BCECE/Documents/LCFRR%20Intentions%20Paper%20Final.pdf

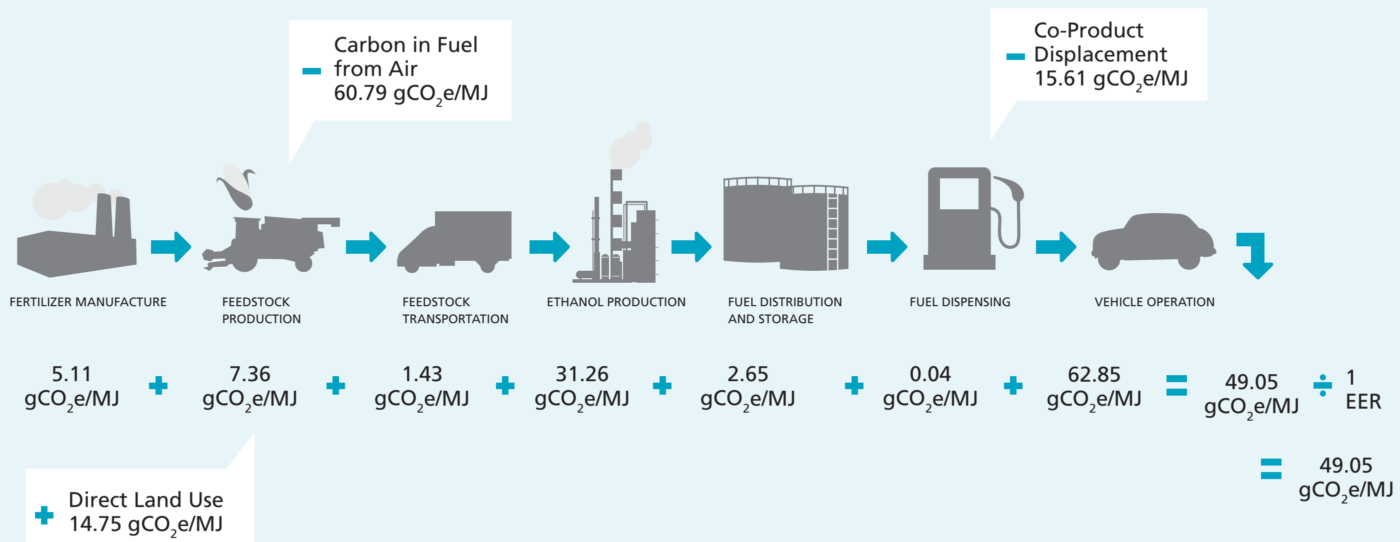
EXAMPLE 1: REFORMULATED GASOLINE (DON O'CONNOR, S&T SQUARED CONSULTANTS – MODIFIED)



Summing the gCO_2e emitted as the MJ of **reformulated gasoline (RFG)** advances through each stage of its lifecycle results in a total CI value of **90.56 gCO_2e/MJ**. The EER value assigned to a standard powertrain used in most light-duty passenger vehicles is 1 (unity), so the CI value remains unaltered. By contrast, BC's RLCFRR applies an EER of 1.2 to diesel-powered vehicles to account for the higher thermal efficiency performance of diesel-cycle engines. As a result, the total unadjusted CI for **ultra-low sulphur diesel** (**ULSD**) - fuel cycle not shown, but similar to that of RFG - is 93.56 gCO_2e/MJ, to which an EER value of 1.2 is applied, resulting in an adjusted CI of **77.97 gCO_2e/MJ**.

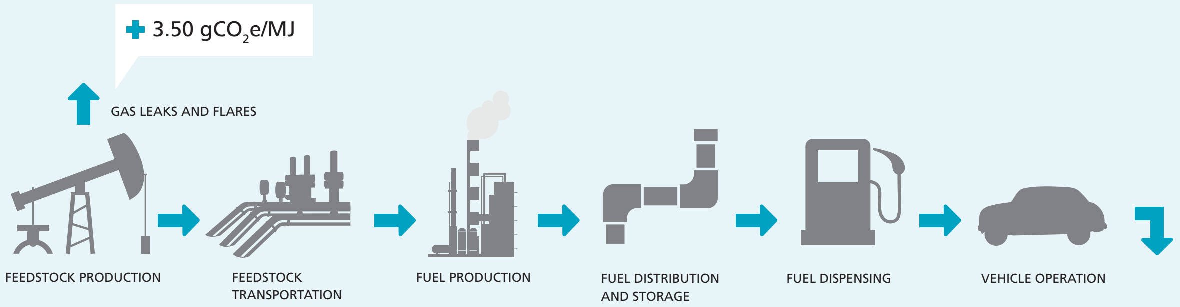
A closer look at the discrete contributions to CI at each stages of the lifecycle reveals that both in the case of RFG and ULSD, approximately 30 per cent of the CI is represented in the process of getting the fuel to the vehicle, while the remaining 70 per cent is represented in the combustion of the fuel to power the vehicle.

EXAMPLE 2: ETHANOL DERIVED FROM CORN (DON O'CONNOR, S&T SQUARED CONSULTANTS – MODIFIED)



The ethanol fuel lifecycle shown above differs from the previous examples of RFG and ULSD in several ways. In particular, while some stages of the ethanol production process require more energy and are more carbon-intense than in gasoline and diesel production. This is offset (in dramatic fashion) by the quantification of CO_2 drawn from the air in the growth of corn (feedstock), through the natural process of photosynthesis. Thus, **ethanol derived from Western Canadian corn** has an average total CI of **49.05 gCO_2e/MJ**. By way of comparison, **wheat-based ethanol** is estimated to have a CI of **40.48 gCO_2e/MJ**. Because ethanol is blended with RFG, the combined CI would be higher than ethanol alone, but lower than RFG. The CI value of similarly blended fuels declines as increasing levels of ethanol are blended into gasoline (or biodiesel into diesel, for example). As with RFG, the EER ascribed to ethanol is 1.

EXAMPLE 3: COMPRESSED NATURAL GAS (DON O'CONNOR, S&T SQUARED CONSULTANTS – MODIFIED)



$$1.71\ \text{gCO}_2\text{e/MJ} + 0.64\ \text{gCO}_2\text{e/MJ} + 1.37\ \text{gCO}_2\text{e/MJ} + 1.93\ \text{gCO}_2\text{e/MJ} + 0.23\ \text{gCO}_2\text{e/MJ} + 52.78\ \text{gCO}_2\text{e/MJ} = 62.16\ \text{gCO}_2\text{e/MJ} \div 1.1\ \text{EER} = 56.51\ \text{gCO}_2\text{e/MJ}$$

Compressed natural gas (CNG) lifecycle is presented to illustrate the CI calculation of a non-liquid fuel source. CNG has a lower CI sum in its lifecycle *up to the tank* than compared to RFG or ethanol, but its total CI is higher than the corn ethanol shown in the previous example. The final unadjusted CI for CNG is 62.16 gCO_2e/MJ; however, **CNG** is assigned an EER value of 1.1, thus the final adjusted value is **56.51 gCO_2e/MJ**.

Other alternative fuel cycles have the potential for even greater reductions in CI. **Electricity**, for example, based on the average CI of power produced in BC, has an unadjusted CI of 13.68 gCO_2e/MJ. When the EER value for electric vehicles is factored in (3.2 due to the higher efficiency with which electric motors generate mechanical power) the final CI is a mere **4.28 gCO_2e/MJ**.

The figures used in these illustrations are the result of regulatory analysis conducted for the BC government utilizing GHGenius, which is a unique model and a LCA tool widely used in Canada by the federal and provincial governments. Using GHGenius, each fuel type is separately analyzed and assessed according to its lifecycle. BC selected GHGenius version 3.15 as its LCA tool, which is different from tool(s) selected by California (which uses GREET) and from those employed by the EU (JRC/BioGrace). Reconciling the differences in the methodological approaches that underlie each of these LCA tools is an important challenge if compliance measures are to incorporate trade in CI credits among jurisdictions. Differences in analytical approaches were discussed at length at the workshop.

Following Parliamentary Secretary Yap's welcoming presentation, the plenary commenced. During the first part, Dr. Anil Baral, John Courtis and Paul Wieringa updated the workshop participants on the status of LCFS regulations in North America and Europe. During second part, Ted Stoner, Robert Cash and Bruce Agnew shared their insights on feasible compliance pathways under the RLCFRR and reflected on prior presentations from policymakers and regulators to provide workshop participants with a perspective from fuel suppliers and end-users.

PLENARY PART 1: Setting the Context for the Day

2.1 Overview of Low-Carbon Fuel Regulations in Various Jurisdictions

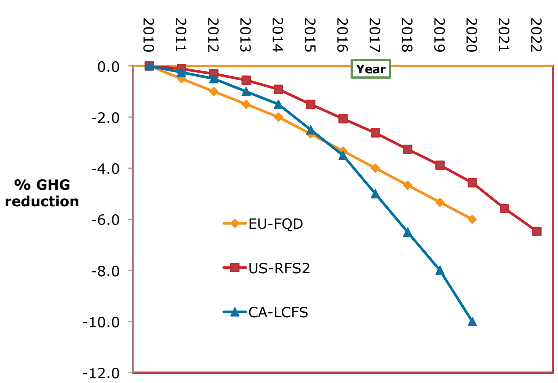
Bio notes: Dr. Anil Baral, Senior Researcher, the International Council on Clean Transportation

Dr. Anil Baral is a Senior Researcher at the International Council on Clean Transportation (ICCT) with expertise on biofuels/bioenergy, lifecycle analysis (LCA) and environmental policy. He has extensively published in peer-reviewed journals in areas of LCA, bioenergy and environmental policy. Prior to joining the ICCT, Anil was actively involved in developing a novel LCA tool called Eco-LCA at the Ohio State University. At the ICCT he works with regulators in the US and Europe assisting the formulation and effective implementation of low-carbon fuel policies and conducts research on LCA and low-carbon fuels. Anil previously worked as environmental coordinator at Martin Chautari, a non-profit organization, conducting research on electric vehicles and promoting alternative fuel vehicles in Kathmandu, Nepal.

Dr. Anil Baral provided a global perspective on climate change policies and regulations in the transportation sector, comparing the California LCFS, the 2012 Standards for Renewable Fuel Standard Program (RFS2) of the US Environmental Protection Agency (EPA), the Renewable Energy Directive and the Fuel Quality Directive (RED/FQD) of the European Union, BC's RLCFRR and the Renewable Transport Fuel Obligation (RTFO) in the United Kingdom.

First, Anil discussed the differences in the expression of targets, sustainability criteria and treatment of indirect land use changes, compliance pathways and the application of market mechanisms employed by each jurisdiction. While there are subtle differences under each of these regulations, the most material is the expression of the targets for the EU FQD, the US RFS2 and the California LCFS, with the latter having the deepest targets to be attained (Figure 1). Notably, BC's GHG reduction target under the RLCFRR is set to match California's. Other jurisdictions with low-carbon regulations under development include Ontario, the Northeast and Mid-Atlantic region and the North-Western states (Oregon and Washington) in the US.

FIGURE 1. COMPARISON OF THE IMPACT OF DIFFERENT LOW-CARBON FUEL POLICIES IN NORTH AMERICA AND EUROPE



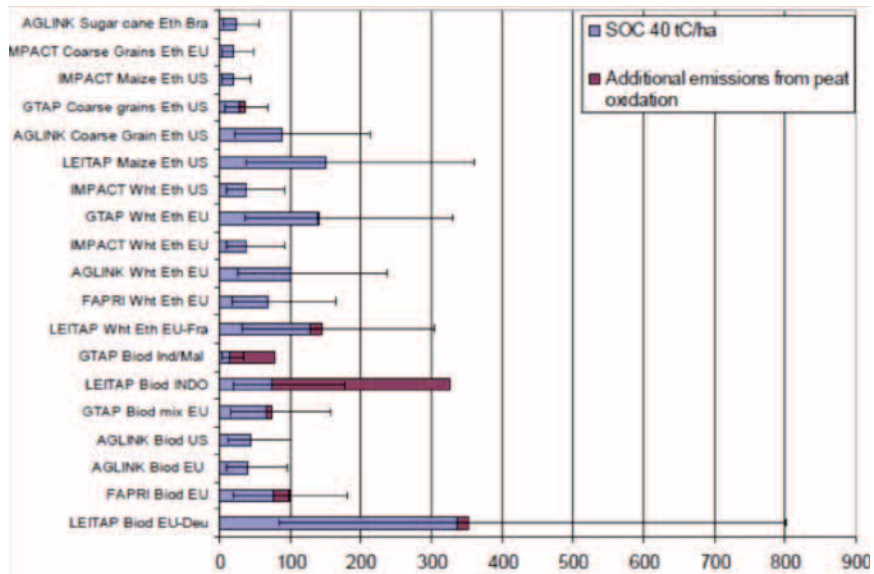
Regs/Features	LCFS-CA	RFS2-US	RED/FQD-EU	LCFS-British Columbia	RTFO-UK
Target	10% GHG reduction	36 Bgal by 2022	10% renewable energy/ 6% GHG reduction	10% GHG reduction	5% biofuel by 2013-2014
Sustainability Criteria	To be developed by 2011	Protection against biodiversity areas	Compliance with basic environmental criteria		RTFO meta and qualifying standards
ILUC	Yes	Yes	No	No	No
Compliance pathway	Biofuels and fossil fuels (CNG, LPG),electricity, hydrogen	Biofuels	Biofuels, hydrogen, electricity, fossil fuels for FQD	Biofuels and fossil fuels	Biofuels
Market Mechanisms	Credit trading	RINs trading	Credits from CDM (FQD)	Credit trading	Tradable "Renewable Transportation Fuel Certificates"

Anil noted that the EU RED, the projected impacts of which are not shown above, requires a broader set of indicators of environmental performance than just GHG emissions and CI, and that some jurisdictions, like California, plan to incorporate sustainability criteria into their LCFS-based regulations in the near future to address, for example, biodiversity and water use impacts of renewable fuel production. The US EPA currently relies on voluntary sustainability provisions in its RFS2 program.

Anil emphasized the importance of addressing indirect land use changes (iLUC) when assessing the CI of fuels. In theory, although biofuels generate similar levels of GHG emissions at the tailpipe as do fossil fuels when combusted in a vehicle's engine, they are nonetheless considered to be less carbon-intense because the biofuel feedstock (e.g., plants that yield sugar for ethanol production or oil for biodiesel), when growing, absorbs carbon from the atmosphere through photosynthesis. However, Anil referenced recent studies of global agricultural markets, which warn that the production of biofuel feedstocks – even if occurring on currently cultivated land – may lead to the conversion of existing forests and grasslands in other locations to meet an ever-growing global demand for arable land. This is unsustainable, as the loss of the carbon sink that was the forested land, for example, contributes to a net increase in CO_2 emissions. The change in land use from forest to agriculture is thus the *indirect* result of increased biofuel production – hence, the term indirect land use change (iLUC).

To account for these potential increases in the lifecycle GHG emissions from production of biofuels, iLUC factors have been calculated; however, their magnitude varies by model. Anil pointed to the California LCFS and the US RFS2 as the only two regulations that currently incorporate iLUC in their provisions, and to the EU's RED/FQD, where the inclusion of iLUC is pending decision. In Europe, progress on decisions relating to iLUC has been delayed until more definitive findings from studies commissioned by the European Commission on iLUC are released. As illustrated in Figure 2, while the magnitude of iLUC on carbon performance varies, depending on the study-specific assumptions its impact is evident.

FIGURE 2. COMPARISON OF ILUC EMISSIONS UNDER DIFFERENT MODELS AND BIOFUEL FEEDSTOCKS



As a result, the European Commission is evaluating four options:

1. Take no action but continue to monitor iLUC
2. Additional sustainability criteria for biofuels likely to induce iLUC
3. Raise the minimum GHG reduction threshold
4. Assign iLUC emissions to biofuels

In addition to iLUC factors, Anil also emphasized the importance of considering the CI values of fuels derived from high-carbon intensity crude oil (HCICO). Currently, the California LCFS requires regulated parties to account for their use of some HCICOs in their crude slates (i.e., crude oil sources they can access), recognizing that production of some crude oils requires more energy to produce (because they are harder to extract from the earth) and to pre-process for refining (because they are composed of heavier substances) than those assumed under the reference case for gasoline and diesel (and thus are more carbon-intense). For example, HCICO can be those that are produced using "thermal recovery methods, bitumen mining, excessive flaring, or upgrading"[3] techniques that result in high GHG emissions. Notably, "since no CI values for HCICO yet exist in the Lookup Tables [used by the regulated parties to calculate CI of their fuel pool], regulated parties are required to develop CI values by using a technically rigorous methodology referenced elsewhere in the regulation."[4]

In Europe, subject to a decision of the European Council, a separate CI value for petrol derived from "tar sands" (107 gCO_2e/MJ) may be adopted. Currently, the FQD regulations encourage reductions in gas flaring and venting during the fuel production process, and provide special credits for the use of carbon capture and storage technologies.

3 California Air Resources Board. (2011). Low Carbon Fuel Standard 2011 Program Review Report. Working Draft, Version 1. Accessed at: **http://www.arb.ca.gov/fuels/lcfs/workgroups/advisorypanel/20111025WorkingDraftReportv.1.pdf**

4 California Air Resources Board. (2011). High Carbon Intensity Crude Oil (Topic 14) Draft Outline. Accessed at: **http://www.arb.ca.gov/fuels/lcfs/workgroups/advisorypanel/20110630_topic14_outline.pdf**

By contrast with the California LCFS and the European regulations, the BC RLCFRR includes heavier crudes in the reference case for gasoline and diesel. While it is important to recognize high CI associated with some crudes. Anil cautioned that HCICO provisions may result in increased GHG emissions due to fuel shuffling (wherein companies, in order to comply with more stringent CI requirements in one jurisdiction, redirect their higher CI crudes and fuel products into non-regulated regions, which offsets the reductions in GHG emissions sought by the policy).

Anil concluded that there was growing interest in LCFS-based regulations as a means to rationalize a growing demand for transportation energy demand while reducing GHG emissions at the same time. However, as these policy tools evolve, such issues as the iLUC risks of biofuels, HCICO impacts on CI and inclusion of sustainability criteria into LCA need to be addressed. Anil left the workshop attendees with a question: how can jurisdictions best incentivize genuine low-carbon fuel production and use under a policy framework that minimizes fuel shuffling?

2.2 California Low-Carbon Fuel Standard

John Courtis began by introducing himself a member of the public and noted that he was not attending as an employee of the California Air Resources Board (CARB).

John started his presentation with a brief background on the California LCFS, reminding that the regulation established a target of 10 per cent reduction of GHG emissions by 2020 compared to a 2006 baseline. The regulation was partially implemented in 2010 and full implementation began in 2011.

The California LCFS applies to any transportation fuel that is sold, supplied, or offered for sale in California, and to any person who, as an obligated party, is responsible for a transportation fuel in a calendar year.[5] The types of transportation fuels to which the California LCFS applies include gasoline, diesel, natural gas, biogas, electricity, hydrogen, biomass and various blends thereof. John noted that significant investments are being made to produce lower carbon fuels, but these efforts are in the early stages and are incremental in nature. While there is no concern with the compliance schedule under the California LCFS at present, as the targets ramp up over time, improvements in fuel quality and supply beyond 2015 come into question.

To determine whether the California LCFS is achieving its goals and whether any unintended consequences have emerged as a result of the regulation, an Advisory Panel was established by CARB in 2011. The Advisory Panel was tasked with conducting a program evaluation (in 2011 and in 2015), developing regulatory changes and gathering comments about proposed amendments via public workshops. John provided background information on some of the topics to be discussed during an upcoming public workshop on October 14th, 2011:

- Separate treatment of gasoline and diesel;
- Establishment of an Expert Working Group to address issues that arise under the LCFS;
- Development of reporting tools;
- Biorefinery registration;
- Approval process for new compliance pathways;
- Establishment of two evaluation periods (2011 and 2015);
- Creation of an Advisory Panel for the first review of the LCFS in 2011 and second review in 2015;
- Regulatory changes to HCICO, iLUC and sustainability provisions under the LCFS.

5 California Air Resources Board. (2011). Proposed Regulation Order. Accessed at: **http://www.arb.ca.gov/fuels/lcfs/regamend/101411regorder.pdf**

Bio Notes: Paul Wieringa, Executive Director, Alternative Energy Policy Branch, BC Ministry of Energy and Mines

Paul Wieringa is responsible for energy efficiency and conservation, bioenergy and new technologies advancement within the Electricity and Alternative Energy Division, Ministry of Energy and Mines. Paul Wieringa was part of a team that developed the "2007 Energy Plan: A Vision for Clean Energy Leadership", particularly the oil and gas component. Prior to assuming the Executive Director position at the Alternative Energy Policy Branch, Paul held various policy and managerial positions within the ministry, as well as at the Ministry of Finance and Crown Agencies Secretariat. In 2002, Paul served as Director of Electricity Policy and focused on developing and implementing the province's 2002 Energy Plan and.

Paul Wieringa holds a Master of Economics from the University of Groningen, the Netherlands.

Next, John described California's ongoing efforts to advance its LCA techniques using a modified version of the GREET model developed by Argonne National Laboratories, called CA-GREET. The new model is expected to include iLUC values from the Global Trade Analysis Project Model (GTAP) developed by Purdue University. Currently CARB is receiving comments and reviewing a new GTAP model, which includes sensitivity evaluation, price-yield elasticity, cropland pasture elasticity and food consumption.

Additional priorities that CARB is working on include efforts to advance the Expert Working Group, which would provide advice on the technically challenging aspects of the California LCFS that continue to evolve as more research and experience are acquired.

John also mentioned that new opportunities to receive credit towards compliance under the California LCFS for the utilization of electric vehicles (EVs) and for the provision of public access to EV charging equipment are being discussed as part of new revisions to the regulation.

Lastly, John spoke to HCICO provisions as an area of change under the California LCFS. Specifically, he identified that new draft regulatory language would incorporate a definition of HCICO and provisions for producers of HCICO to opt-in as a regulated party under the regulation. John explained that these changes would enable the "upstream" producers of more carbon-intense oil to disentangle their discrete contributions to the overall CI of the gasoline and diesel refined from their product and sold by the "downstream" producers, which are also regulated parties.

Changes to the California LCFS underscore that this regulation is dynamic and needs to incorporate new science and ongoing developments as it evolves. To conclude, John shared a number of success stories that have emerged since the introduction of the LCFS in California, such as increased production of biofuels, improved fuel quality and new investments into alternative fuels production.

2.3 Low-Carbon Fuel Regulations in the BC Context

Following John Courtis's presentation about the California LCFS, Paul Wieringa, the Executive Director at Alternative Energy Branch of the BC Ministry of Energy and Mines provided a context for the low-carbon fuel regulations in BC.

At the time low-carbon fuel regulations were considered in BC in 2007, the transportation sector accounted for 36 per cent of total GHG emissions in the province, with light-duty and heavy-duty vehicle sectors each accounting for two-fifths of these emissions. As with other provinces, BC was subject to complying with federally-mandated *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* and the *Renewable Fuels Regulations*. To curb transportation sector emissions further, BC passed the *GHG Reduction (Renewable and Low Carbon Fuels Requirements) Act*, the *Carbon Tax Act* and the *Clean Energy Act* as part of the 2007 Energy Plan and the 2008 Climate Action Plan. In 2009, the *Renewable and Low Carbon Fuel Requirements Regulation* (RLCFRR) was introduced under the *GHG Reduction Act*, and came into force January 1, 2010. In his presentation, Paul described important aspects of the RLCFRR and highlighted some key differences between the regulation and the California LCFS.

Paul provided an overview of the main components of the RLCFRR, describing its market-based features and highlighting provisions that ensure its flexibility (i.e., provisions that allow new fuel alternatives to be considered under the regulation once they become economically feasible).

The RLCFRR prescribes annual reductions in the CI of transportation fuels sold in BC in order to achieve an overall 10 per cent reduction in the CI of regulated fuels by 2020, using 2010 as a baseline. The fuels regulated under the RLCFRR include gasoline, diesel, ethanol, biodiesel, propane, natural gas and other fuels or forms of energy, such as electricity, when used for transportation. The RLCFRR applies to a first-time sale of the aforementioned fuels after they are manufactured or imported into BC. Thus, the RLCFRR typically applies to fuel suppliers, who sell fuels to local distributors or to final fuel users in the province.

Similar to the California LCFS, default values for the CI of transportation fuels have been established under the RLCFRR, along with an initial baseline for the average CI of all fuel supplied in BC. The maximum allowable average CI for transportation fuels is incrementally lowered every year (Table 1), and the regulated parties are required to submit annual reports to demonstrate their compliance in meeting each year's CI limit.

To comply with the RLCFRR, the regulated parties can reduce the CI of their transportation fuels by improving refining processes or implementing carbon management practices, such as carbon capture and storage. Alternatively, they can change their transportation fuel supply mix by supplying proportionately more low-carbon fuels. Lastly, they can acquire CI credits to apply toward their compliance from other regulated parties (credits are accumulated according to the extent to which a regulated party surpasses prescribed CI levels).

Paul noted that the regulated parties who provided less than a total of 200 million litres of gasoline and diesel class fuels in 2010 are exempt from the requirements to integrate renewable content into their transportation fuel supply mix. The exemption reduces over time, and applies only to those regulated parties who provide less than 50 million litres in 2011 and 10 million litres in 2012. Paul asserted that the cost of fuel for consumers as a result of the RLCFRR will be nominal and should disappear when more renewable fuels become available. Moreover, vehicle performance should not be affected.

TABLE 1. COMPLIANCE SCHEDULE

Calendar Year	Cumulative reduction (%)	Limit (gCO_2e/MJ)	Calendar Year	Cumulative reduction (%)	Limit (gCO_2e/MJ)
2010*	0.00	83.47†	2015	2.50	81.38
2011#	0.25	83.26	2016	3.50	80.55
2012	0.50	83.05	2017	5.00	79.30
2013	1.00	82.64	2018	6.50	78.04
2014	1.50	82.22	2019	8.00	76.79
			2020	10.0	75.12

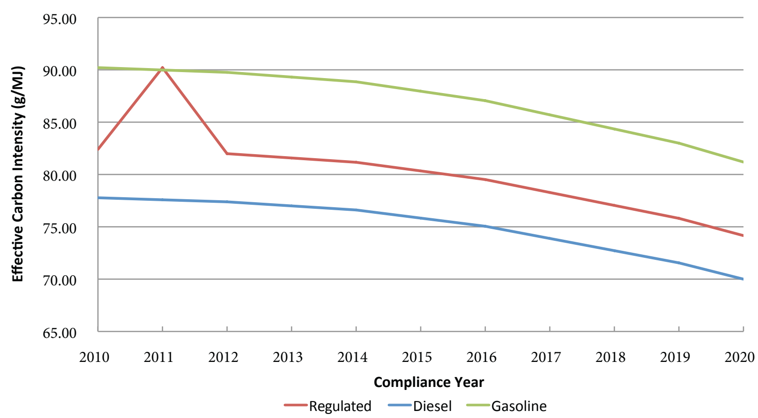
* 2010 is a reporting only year

† This is the CI baseline.

The requirement for 2011 was maintained at 2010 levels while a review of the policy was conducted

Paul noted that the RLCFRR was amended to make 2010 a "reporting only" year for CI requirements. The province expects the compliance to be achieved with the addition of renewable fuels into the transportation fuels mix in the initial years of the regulation, with much of the early emphasis being placed on biofuels (Figure 3). However, beyond 2015, the availability of viable infrastructure and technological solutions, as well as securing sufficient volumes of lower carbon fuels, may pose compliance challenges for the regulated parties. For example, there are significant numbers of flex fuel vehicles available at the moment, however, there is little E85 dispensing infrastructure available in the province.

FIGURE 3. EFFECTIVE CI EXPECTED OVER THE RLCFRR COMPLIANCE PERIOD



Deeper reductions that are required further along the compliance pathway may require second generation biofuels that provide more CI reduction potential. Paul noted that research and development and investment in infrastructure are required to provide these markets and develop a new supply in Canada and BC. Whereas the majority of the biofuels are coming from the US at the moment, the role of incentives will be important to develop future supply locally.

Paul noted that while a diverse mix of low-carbon fuel sources is important to achieving the province's policy objectives under the RLCFRR, there is also a need to address current barriers to integration of such alternatives into the transportation sector fuel mix. For example, the roles that utilities and fuel suppliers play in the electrification of vehicles need to be defined; and new business models need to be developed to create investment cases for fuelling and charging infrastructure, as well as for vehicles themselves. Paul illustrated this point by referring to a number of buses in Whistler, BC, that currently make use of locally-developed hydrogen fuel cell technology, supported by six hydrogen fuelling stations. Similarly, the benefits to end-consumers of less common options, such as natural gas, propane and hydrogen, will need to be clearly communicated. To this end, investments in the development and piloting of hydrogen in fuel cells could help to create jobs in the province.

Paul highlighted several challenges the province is facing as it moves forward with efforts to reduce carbon from the transportation sector under the RLCFRR. For example, there is recognition that some biofuels may have higher CIs than is currently assumed if iLUC and sustainability concerns are factored in. Thus, questions exist on the optimal ways to accurately measure these effects and account for them under the RLCFRR. To this end, the province is paying close attention to the developments in California and Europe for lessons learned. Other challenges pertain to CI credit validation and trading within the province and across jurisdictions where LCFS-based regulations exist. For example, if traditional fuel suppliers choose to refrain from trading CI credits, which is permitted as a compliance flexibility mechanism under the regulation, then the province may consider whether it should allow other, non-traditional fuel suppliers to voluntarily become regulated parties to help broaden and develop the market for credit-trading under the RLCFRR.

The treatment of gasoline and diesel under the RLCFRR is another important consideration for the province. The RLCFRR recognizes that diesel, when combusted in a diesel-cycle engine, converts energy more efficiently, such that fewer carbon emissions are produced per unit of energy used than gasoline combusted in a standard gasoline-cycle engine. Thus, despite the fact that burning a litre of diesel produces more carbon emissions, it can be considered a lower carbon fuel from a lifecycle perspective, because less fuel is used and fewer emissions are produced. By contrast, the California LCFS does not consider diesel a low-carbon fuel. By setting separate CI baselines for gasoline and for diesel, from which fuel suppliers' CI reductions are measured, the incentive to promote diesel over gasoline is eliminated.

To conclude his presentation, Paul described opportunities that might arise from harmonization of low-carbon policies with other jurisdictions, such as Alberta, the main supplier of fuel to BC, and California, where opportunities for collaboration could exist, including CI validation and credit trading.

Following the first part of the plenary, the floor was opened to questions from the workshop participants. First, the speakers were asked to comment on the amendments to the LCFS-based regulations to include HCICO provisions. The general response was that government sought to foster a motivation to innovate low-carbon fuel solutions without picking winners. The opinion was that this required a fair benchmarking mechanism that could be applied evenly and objectively across a range of fuel sources, and inclusive of the entire fuel supply mix in any jurisdiction. In California, CARB has considered five potential HCICO production processes, and is now investigating these processes in real operations to establish appropriate CI values.

Next, the speakers were asked to speculate on what they thought were the biggest challenges going forward with LCFS-based regulations and possible solutions. In BC, a number of challenges were discussed, such as limited staffing resources, limited understanding of the types of technologies that will emerge, means of addressing these developments from a planning perspective, as well as challenges with incorporating iLUC and sustainability principles into the regulation. In California, some of the challenges noted were the uncertainty about the availability and the diversity of alternative fuels into the future, creation of a favorable policy and fiscal environment for the industry needed to advance the regulations, and difficulties in achieving additional CI and GHG emissions reductions beyond 2020. Addressing iLUC and sustainability was noted as a challenge for California as well; however, it is expected that CARB will address these issues over the next two years. A concern was expressed on this point by an audience member, who explained that when the modeling activity on iLUC in California was examined, it was discovered that the lifecycle model outputs were extremely difficult to validate with real-world observation. Since CARB's Expert Panel decided that this issue would not be feasible to address, the validation and the verification of model accuracy on iLUC factors remains incomplete.

Another topic discussed was the possibility of an inter-jurisdiction collaboration on LCFS-based regulations. Two different viewpoints emerged during the discussion: that inter-jurisdictional collaboration might work in the context of this complex policy; and, conversely, that due to the different fuel options, infrastructure and available technologies across the jurisdictions; an inter-jurisdictional collaboration would not be feasible. Differences in the assumptions relating to HCICO, which lead to different CI values in California and BC, were referred to here.

The discussion then segued into the effectiveness of LCFS-based regulations compared to other policy options, and the workshop participants questioned whether a comparative analysis of these options had been conducted. In California, the analysis preceding the passage of the *Assembly Bill 32: Global Warming Solutions Act* (2006) investigated all options available for emissions reductions in the transportation sector. The analysis led to the conclusion that there was no single approach that would overcome the public policy challenges inherent in the transportation sector, and that a bundle of policy options, including carbon tax, LCFS- and emissions-based regulations would be the most effective. As part of the analysis, it was noted that California LCFS is a cost-effective means of achieving GHG emissions reductions, though perhaps not cost-optimal. In BC, a similar analysis took place, which arrived at a similar conclusion.

Lastly, a question regarding credit trading under the LCFS regulations was raised - whether there was any effort placed on price discovery for notional transfers of CI credits, and whether there would be any advice available on this topic in the near future. In BC, no credit trading took place in 2010. Furthermore, the system to facilitate these transactions had not yet been developed. In California, transaction information was being collected and could offer guidance in the near term. It was suggested that the validation of this information would lend useful lessons on the credit trading aspect of LCFS.

PLENARY PART 2: BC Context and Stakeholder Perspectives

Bio Notes: Ted Stoner, Vice President, Western Region, Canadian Petroleum Products Institute

Ted Stoner has worked in the petroleum industry for 33 years, primarily in various operations roles. He retired as Manager at Dartmouth Refinery in 2002 and assumed his current position as Vice President, Western Division, Canadian Petroleum Products Institute. Ted has been engaged with the four Western Provinces on the development of various renewable fuels files.

2.4 BC Renewable & Low-Carbon Fuels Requirements Regulation – Industry Perspectives

Ted Stoner from the Canadian Petroleum Products Institute (CPPI) provided the workshop participants with an industry perspective on the LCSF regulations. CPPI is a national association of Canadian refiners and marketers of petroleum products. Its members include Chevron Canada Limited, Husky Energy Inc., Imperial Oil Limited, North Atlantic Refining Limited, NOVA Chemicals (Canada) Limited, Parkland Fuel Corporation, Shell Canada Products, Suncor Energy Products Partnership, Ultramar Ltd. and Bitumen Inc. CPPI's purpose is to serve and represent the petroleum industry with respect to environment, health and safety and business issues. CPPI's membership represents all of the refiners obligated (i.e., subject to compliance and enforcement) under the RLCFRR.

The CPPI met with the BC Government on several occasions to discuss the RLCFRR. The CPPI members raised four main concerns in regard to the regulation.

First, CPPI members viewed the 10 per cent CI reduction target required by the regulation by 2020 as overly ambitious. CPPI members were concerned about meeting annual RLCFRR CI limits in light of current original equipment manufacturer (OEM) blending limits, Canadian climate challenges and lack of availability of low CI biofuels.

Second, CPPI members were concerned that fuel suppliers have little or no influence on the development and commercialization of alternatively fuelled vehicles, such as those powered by compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (LPG), hydrogen (H_2) and EVs, or on the market acceptance and adoption of alternatively-fuelled vehicles. Yet, the development and commercialization of such vehicle technology is nevertheless necessary to meet current RLCFRR objectives.

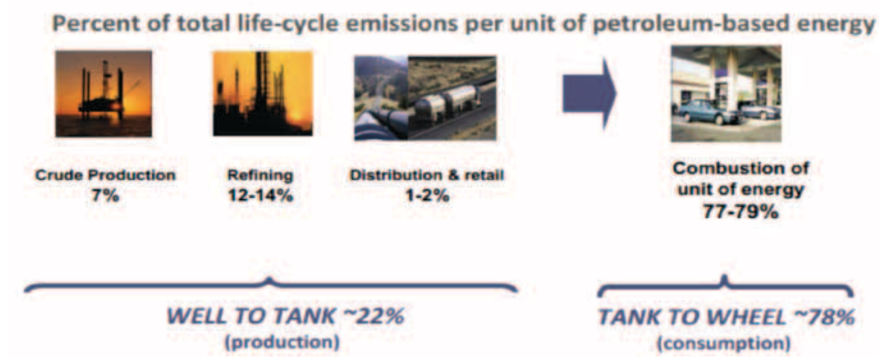
Third, CPPI members felt that a CI limits that vary from batch to batch of producers' petroleum fuels could have unintended consequences, such as shuffling of high CI products from regulated to non-regulated jurisdictions, preventing the realization of the overall reductions in GHG emissions. "Fixing" CI values for gasoline and diesel, in which all gasoline and diesel products are assigned a common CI value, could help to avoid differentiation of crude and refined petroleum products.

Fourth, the CPPI members viewed RLCFRR as a complex and costly option relative to other GHG emissions reduction alternatives. To this end, a study by Purvin and Gertz was cited, in which the incremental cost of reaching the CI targets under the regulation was estimated at $420 per tonne of CO_2e emissions avoided.

Ted conveyed the CPPI member concern that blending biofuels to the current blending maximums will not achieve the required reductions in CI. He characterized the lifecycle GHG emissions per unit of petroleum-based energy using an LCA graphic, illustrating the fraction of total emissions from crude production, refining and distribution, as well as retailing (i.e., "production" or "well-to-tank" part of the fuel lifecycle), which was estimated to be approximately 22 per cent (Figure 4) and estimated a significantly higher fraction of emissions pertaining to the combustion of petroleum to power the vehicle (i.e., "consumption" or "tank-to-wheel" part of the fuel lifecycle) at approximately 78 per cent. The graph illustrates that while improvements in the extraction and manufacturing processes can lead to lower emissions, much higher reductions can be achieved in the conversion of fuel to useful energy within the vehicle itself.

Note: The RLCFRR mandates reduction of total Well-to-Wheel emissions CI by 10 per cent

FIGURE 4. LCA OF GHG EMISSIONS PER UNIT OF PETROLEUM-BASED PRODUCT ENERGY DURING DIFFERENT LIFECYCLE STAGES FROM PRODUCTION TO USE



Next, Ted elaborated on the challenges of establishing the necessary infrastructure for alternative fuels. He cited *Are We Ready to Step off the Gas? Preparing for the Impacts of Alternative Fuel Vehicles* report prepared by the Conference Board of Canada in April 2011:

"The broad adoption of these alternative vehicle technologies will require substantial changes in fuelling infrastructure and consumer practices." and,

"New performance standards and regulations for systems, designs, infrastructure, and education will have to play a key role in technological change."

The report underscored the need to change infrastructure and consumer habits and practices if alternative vehicle technologies gain wider adoption.

Lastly, Ted noted that existing policies, including the *Specified Gas Emitters Regulation* in Alberta and the *Carbon Tax Act* in BC, already address GHG emissions from refining and production as large industrial sources. There is a concern that the redundancy of addressing these emissions through the RLCFRR could further disadvantage Canadian-based crude oil products. Thus, the CPPI recommends a fixed gasoline CI and a fixed diesel CI, which avoids the focus on crude product differentiation.

Ted summarized his presentation by restating a number of concerns that the CPPI has with the RLCFRR. Namely, that the current compliance pathway cannot achieve the 10 per cent CI reduction required by 2020. Secondly, the development of the technology and markets required for future compliance with the regulation are outside of CPPI members' control. Thirdly, that the differentiation of HCICOs should be avoided to mitigate fuel shuffling and limit unintended consequences. Lastly, that the RLCFRR is a complex and costly regulation relative to other policy alternatives, and that its expected economic and environmental impacts are not well understood. Ted closed his presentation with an advice that more effort is needed to understand how the RLCFRR can balance GHG emissions reductions with economic growth.

Bio Notes: Robert Cash, Environmental Manager, Archer Daniels Midland Canada

Robert Cash is the Canadian Environmental Manager for Archer Daniels Midland Canada (ADM) and has over 20 years of environmental engineering experience and consulting in the industry. Robert advises on technical, compliance, and government relations matters for all aspects of environmental management for ADM's biofuel, oilseed, feed/premix, wheat flour, starch/gluten, grain and chocolate/cocoa processing facilities in Canada. Robert is a Canadian expert and delegate to the ISO 13065 technical committee on Sustainability Criteria for Bioenergy and has just returned from the Nairobi meeting of the subcommittee establishing sustainability principles, criteria, and indicators for bioenergy.

2.5 Implications and Opportunities: A Biofuel Producer's Perspective

Robert Cash, Environmental Manager at Archer Daniels Midland (ADM) Canada, and a Canadian expert and delegate to the ISO 13065 technical committee on Sustainability Criteria for Bioenergy, shared Canadian biofuel producers' perspectives on RLCFRR.

ADM is a global producer of biofuel feedstocks and biofuels, with 30,000 employees, 265 processing plants, operations in over 75 countries and $81 billion in revenue as of 2011 fiscal year. ADM processes crops into hundreds of products for food, animal feed, chemical and energy uses. The company processes 66,000 MT of corn, 95,000 MT of oilseeds, 28,000 MT of wheat and 3,000 MT of cocoa beans each day. ADM produces 1.6 billion litres of biofuel per year through 7 ethanol and 4 biodiesel plants and distributes fuels through 57 ethanol and 5 biodiesel terminal locations across the US. Robert highlighted ADM's diverse inputs and product portfolio, which enables great flexibility in outputs, thereby allowing ADM to optimize the company's value proposition (Figure 5 and Figure 6).

FIGURE 5. DIVERSE INPUTS TO ADM'S NORTH AMERICAN PRODUCT PORTFOLIO

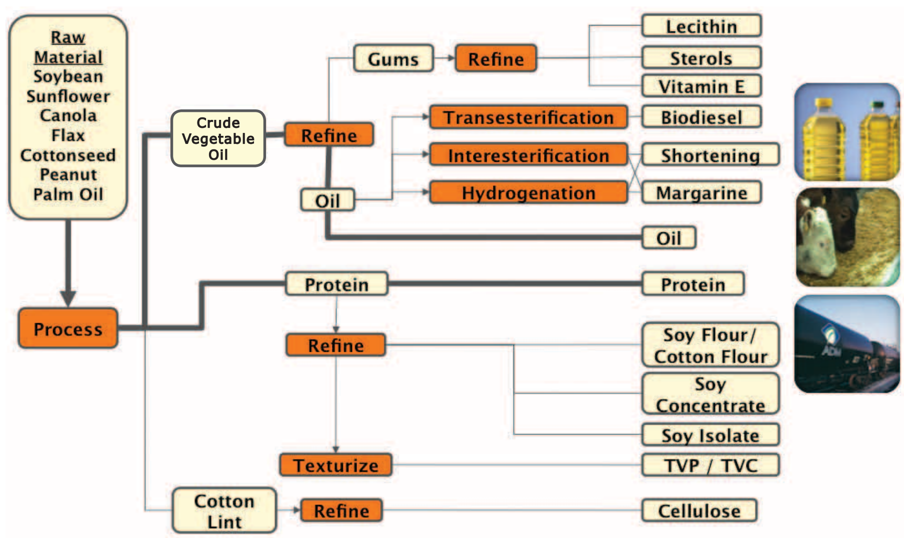
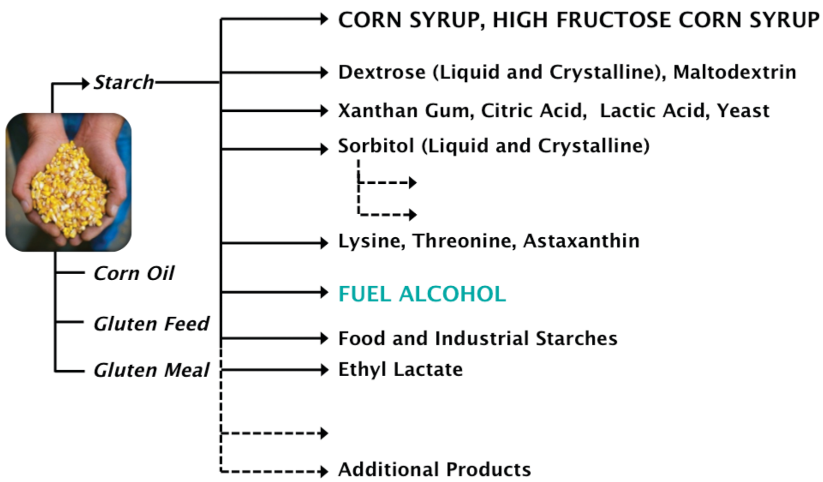
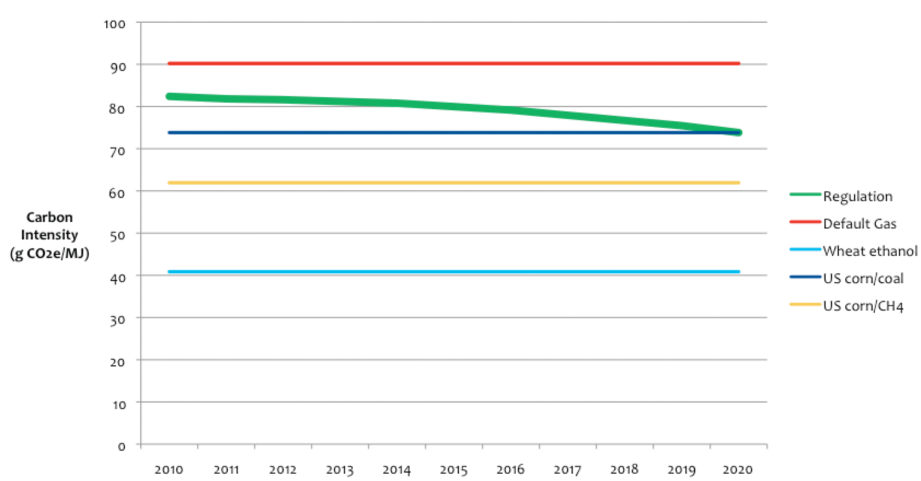


FIGURE 6. RANGE OF PRODUCT OUTPUTS FROM CORN PROCESSING



Robert illustrated that fuel blending can be a key component in meeting the CI targets set out under the RLCFRR regulation (Figure 7):

FIGURE 7. PREDICTED CI OVER COMPLIANCE PERIOD USING FUEL BLENDING UNDER LCFS REGULATIONS



Robert then discussed the emergence of flexible fuel vehicles (FFVs), designed to run on gasoline or a blend of gasoline and ethanol, and noted that in the US the rate of market adoption of these vehicles is higher than in Canada. For example, FFVs capable of running on a blend of up to 15 per cent ethanol (E15) are a reality in US; E85 FFVs are also more commonplace; and both types are expected to play a significant role in meeting CI targets under the California LCFS.

Robert mentioned that there are challenges associated with using default CI values for modelling and reaching targets under the LCFS regulations. He asserted that CI values need to be derived in a science-based manner, supported by real-life, evidence-based data to inform policy. Currently, the estimation of CI for all fuel types is an ongoing challenge, as are the estimates of the potential volumes; however, both are important to modelling efforts, as well as to achieving compliance milestones.

Robert concluded the presentation by stressing the need for market-based solutions and incentives to the industry as two critical components of a forward-looking approach to reducing CI, realistically and ambitiously, while balancing stability and flexibility in regulation.

Bio Notes: Bruce Agnew, Director, Cascadia Center for Regional Development, Discovery Institute

Since 1993, Bruce Agnew has been the director of the Cascadia Center for Regional Development at the Discovery Institute in Seattle. The Cascadia Center is a private, non-profit public policy center engaged in promoting national and regional passenger rail, cross-border freight mobility, US – Canada border issues and sustainable community development.

Bruce is a Chair of an Advisory Committee to the Commission for Environmental Cooperation chartered by NAFTA, member of the Steering Committee of the West Coast Corridor Coalition, state Executive Board of the Washington Conservation Voters and Executive Board of the Can Am Border Trade Alliance based in New York.

From 1987-93, Bruce was Chief of Staff for US Representative John Miller from Washington state's First District. Before his congressional service, Bruce was elected to two terms on the Snohomish County Council and served as President of the Puget Sound Regional Council in 1985.

Bruce is a 1974 graduate of Stanford University and a 1977 graduate of U.C. Berkeley Law School.

2.6 Low-Carbon Fuels in the BC Context

Bruce Agnew's presentation concluded the second part of the opening plenary. Bruce conveyed the concerns of end-users in various transportation modes, including air, rail, marine and the trucking industry as apparent in his work along the West Coast of North America. Throughout the presentation, Bruce emphasized the need for harmonization of LCFS from the perspective of the North American Free Trade Agreement (NAFTA) and the North American Agreement on Environmental Cooperation (NAAEC), thus including Mexico into any forthcoming low-carbon fuel partnerships.

Bruce stressed the importance of considering the needs of end-users when establishing low-carbon fuel regulations and policy. He emphasized the need to need to understand the implications of LCFS on the trucking industry, which is responsible for hauling most of the produce in North America, and thus has a significant weighting on the outcomes of any fuel and transportation policy.

Bruce asserted that jurisdictions need to take advantage of simple options and obtain benefits from "low-hanging fruit". For example, small improvements from fuel savings have a significant cumulative impact in terms of GHG emissions reductions. Where new regulations require an industry to adopt expensive new technologies, the government has a role to play in fine-tuning the incentives to ensure that adoption occurs. In relation to the trucking industry, Bruce suggested a tax credit ($65,000 per new vehicle purchased) as an incentive option, noting that other incentives need to be investigated to make affordable the retrofits of existing truck fleets.

One effective way for jurisdictions to incent technological development is through making investments in pilot projects for new technologies. By creating conditions for innovation, lessons learned and business cases can be shared with industry and the public. Bruce profiled innovative transportation initiatives underway in Whistler, BC, where investments were made into electricity- and hydrogen-powered vehicles and the necessary fuelling stations. Another example that Bruce referred to was the SmartWay Upgrades program administered by the US EPA. The program was set up to help small trucking firms lower their fuel costs and carbon footprints through the use of innovative loans to purchase idling and emissions reduction technologies.[6] Moreover, as part of the program, the US EPA used a novel education format to help truckers understand the paybacks associated with investing in energy efficiency improvements to their vehicles.

6 US EPA. *SmartWay Financing Program-Financing Opportunities.* http://www.epa.gov/smartway/financing/govt-funding.htm

Reflecting on his knowledge as a Chair of an Advisory Committee to the Commission for Environmental Cooperation chartered by NAFTA, Bruce then spoke to the importance of harmonization in cross-border trade. An integrated freight transportation network among the US, Mexico and Canada may help reduce congestion problems at the borders, and, if supported by required sufficient infrastructure, such as EV quick-charging stations along travel corridors, may help advance low-carbon fuel vehicle technologies and create market demand. Bruce mentioned that he is working on a project with FortisBC to map alternative fuelling stations and travel corridors, in order to gain understanding of the infrastructure capacity required to support alternative fuels in the transportation sector in BC.

Bruce concluded his presentation by answering questions about the lack of penetration for E85 distribution in Canada. Bruce suggested that the market up-take for E85 fuel versus the number of E85-compatible vehicles on the road illustrates that there is not sufficient demand to warrant the investment in specialized fuel storage tanks and dispensing equipment, which costs $60,000 - $80,000 per fuelling station. As a result, E85 vehicle owners most often fuel their vehicles using regular gasoline. In Bruce's view, this reinforces the need to support infrastructure investment, such as alternative fuelling stations, to advance market adoption of alternative fuels.

During the ensuing dialogue, it was suggested that the optimal path for LCFS regulations is one that is not prescriptive, but which fosters conditions for a more open market, enabling industry to innovate and to realize economic gains from its innovations. It was cautioned, however, that the market alone is not sufficient to create the type of transformation that is needed to comply with CI targets beyond 2015 under the RLCFRR in BC. While much is being done by the fuel suppliers to improve operational efficiency and to advance alternative fuel options, including biofuels, considerable investment needs to be made by the government to ensure continued innovation in advance of the 2015 challenge.

Chapter 3: Policymaking and Regulation: Assessing LCFS and Other Policy Frameworks in a BC Context

POLLUTION PROBE
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Chapter 3: Policymaking and Regulation: Assessing LCFS and Other Policy Frameworks in a BC Context

Policymakers and regulators need tangible and practical processes to make policy work. The *Policymaking and Regulation: Assessing LCFS and Other Policy Frameworks in a BC Context* session sought to build on the topics covered in the opening plenary and address in more detail the question of what policymakers and regulators need to design, implement, monitor and ensure compliance under LCFS, in a practical sense. How does LCFS align with established policy and regulatory assessment criteria? How would LCFS integrate with other regulatory regimes that aim to reduce GHG emissions? What alternative comprehensive frameworks for managing transportation energy use and emissions should be considered?

To address these and other questions and to help the workshop participants explore the challenges and implications of LCFS, Pollution Probe invited six experts to the workshop to share their perspectives and animate the dialogue. The speakers' presentations and the Q&As that followed constituted Session 1-3 A of the workshop agenda.

The first three speakers, Dr. Sonia Yeh, Bill Greenizan and James Uihlein focused on the various tools with which policymakers and regulators could potentially manage the implementation and enforcement of LCFS, and the inherent challenges and limitations of the tools. The three speakers, who followed, Gerry Ertel, Doug Hooper and Dr. David Stern, focused on the other transportation and emissions policy frameworks that need to be considered for their potential to complement or conflict with LCFS. In addition, alternative approaches for reducing the CI of the transportation sector in BC were explored in this session.

Bio notes: Dr. Sonia Yeh, Research Scientist, Institute of Transportation Studies, University of California, Davis

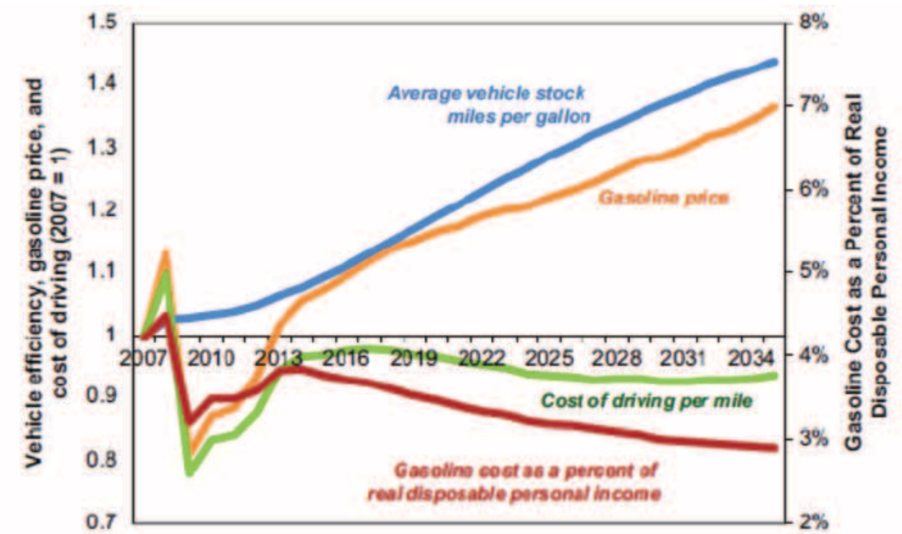
Sonia Yeh is a Research Scientist at the Institute of Transportation Studies and a faculty member of Graduate Group in Transportation Technology and Policy, University of California, Davis. Her research interest is to advance the understanding of future energy systems and their environmental and social impacts and to seek policy solutions to improve their sustainability performance. Her fields of expertise include energy system modeling, policy analysis, lifecycle assessment and learning-by-doing. She has been involved with the design and implementation of California climate policies, including the California Global Warming Solutions Act (AB32) and the Low Carbon Fuel Standard (LCFS) and served on many of the advisory panels. She is a committee member of the Transportation Research Board of the National Academies.

3.1 Towards a Universal Low-Carbon Fuel Standard: Short-, Medium- and Long-Term Views of Mitigating Transportation GHG Emissions Challenges

Dr. Sonia Yeh presented on the overall policy framework within which LCFS is intended to work. By drawing on climate change policy in California as an example, she articulated the specific role that California LCFS plays alongside other transportation emissions regulations in that state. Sonia also explained some of the implementation and monitoring challenges experienced to date and discussed the solutions that are being pursued. Looking forward to 2030 and beyond, Sonia argued the need for additional policy beyond LCFS to meet long-term objectives on GHG emissions reductions. The information presented by Sonia laid the foundation for the speakers who followed.

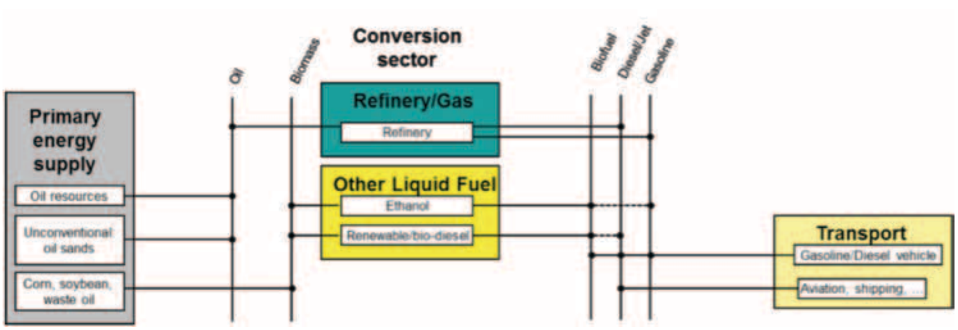
Sonia began by establishing the motivation for regulatory intervention in the transportation sector, highlighting the factors that drive up market demand for transportation energy use in the future. As in John German's presentation (see Section 4.2), Sonia pointed out that although the *price* of fuel is expected to increase over time, fuel efficiency improvements in new vehicles will reduce the real *cost* of driving (Figure 8).

FIGURE 8. ILLUSTRATION OF MARKET TRENDS IN FUEL EFFICIENCY IMPROVEMENTS AND FUEL COST OVER TIME



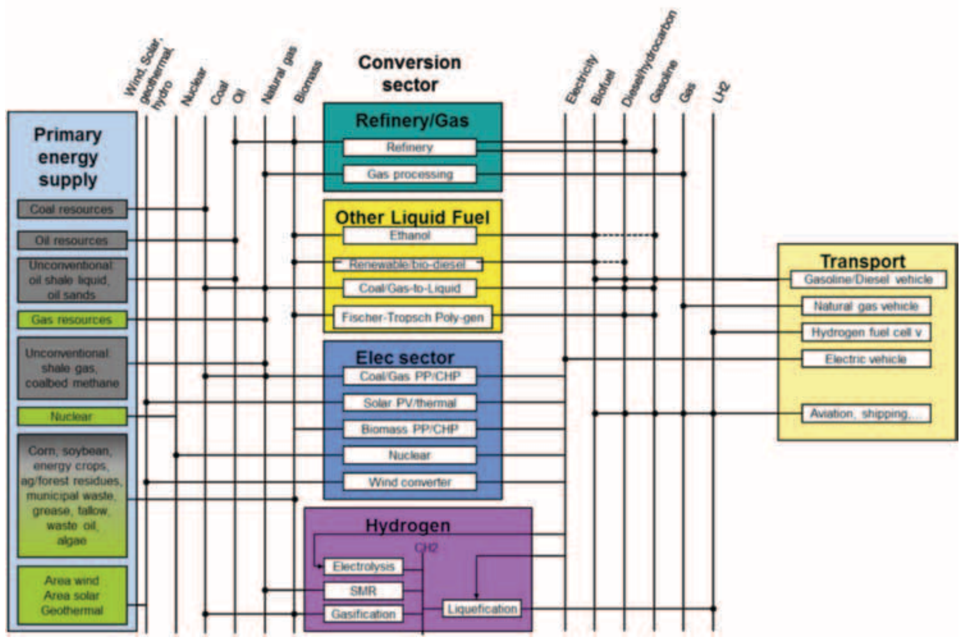
She noted that broad-based carbon pricing measures, such as economy-wide GHG emissions cap-and-trade, are not expected to generate strong and targeted signals that will substantially mitigate the demand for transportation fuels. Thus, the contribution of the transportation sector to deep reductions in GHG emissions requires regulatory measures. Sonia further described the diversity of energy options to power transportation systems as narrow, with few primary energy inputs, and highly carbon-intense, dominated by gasoline, diesel and various aviation and shipping fuels (Figure 9).

FIGURE 9. PRIMARY TRANSPORTATION FUEL PROCESSING PATHWAYS



Sonia expressed that the sustainability of future transportation systems requires a more diverse array of energy options, with high carbon fuels offset by a supply of low-carbon fuels (Figure 10).

FIGURE 10. POTENTIAL PRIMARY FUEL OPTIONS FOR FUTURE TRANSPORTATION SYSTEMS



Due to the numerous factors governing transportation sector emissions, a portfolio of policies is needed, explained Sonia. Preferably performance-based and market-based, these policies should target vehicle technology, fuels and their use across all modes of transportation (i.e., road, air, rail and marine). Furthermore, these policies must address what Sonia referenced as "market failures", including inadequate investments in research and development and economic externalities, such as air pollution. They must also consider the unique market conditions and barriers that characterize the transportation sector:

- Coordination (network effects) among fuel producers, vehicle manufacturers and fuel distributors;
- Conservative (inelastic) consumer behaviour;
- Large energy security externalities;
- Long-time horizons needed for return on fuel infrastructure investments;
- Lack of fuel-on-fuel competition;
- Diffuse nature of the biofuel industries; and
- Market power of oil companies.

Sonia also mentioned that unlike other sectors of the economy, transportation GHG emission-intensity is increasing. Investment in more carbon-intense crude oils, such as oil sands and oil shale, and gas-to-liquid and coal-to-liquid fuels, will exacerbate this trend.

To make substantial progress on managing GHG emissions downward, Sonia advised action under four key policy areas:

1. Vehicle energy efficiency

- Fuel efficiency and GHG emissions performance standards

2. Fuel CI

- Renewable Fuels Standard (RFS)
- Low-Carbon Fuel Standard (LCFS)

3. Advanced fuel and vehicle technology

- Zero-Emission Vehicle (ZEV) program
- Advanced/alternative energy infrastructure policies

4. Better management and Vehicle Miles Travelled (VMT)

- Pricing of roads and vehicle use, land use management, public transport (plus systems management and the promotion of "eco-driving")

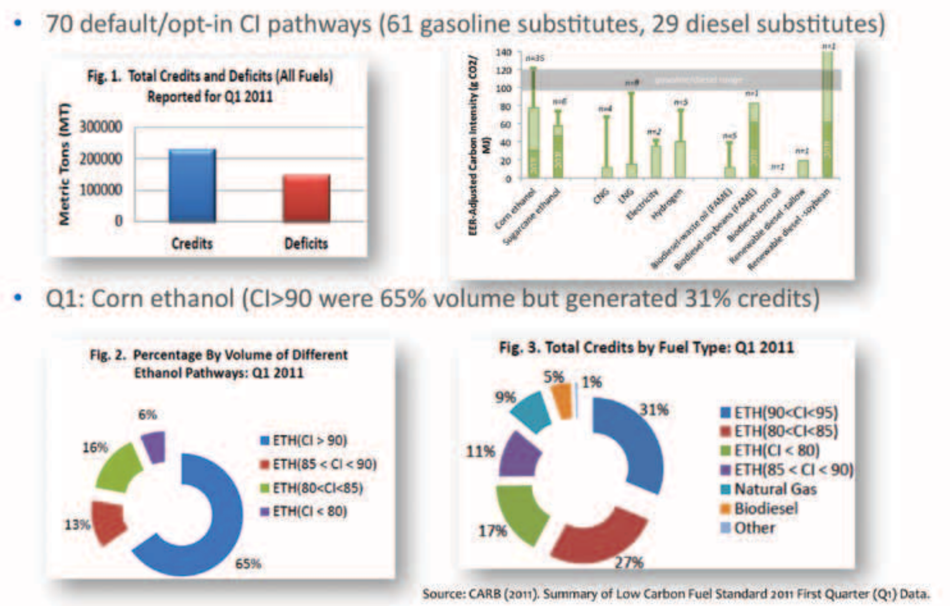
Sonia distinguished between RFS and California LCFS, saying the RFS is a step in the right direction, as it mandates the use of lower carbon biofuels, measures them on a lifecycle basis, but it has shortcomings. Namely, it does not promote the use of lower carbon fuels that are not biofuels, the scope of fuels that qualify are narrow and prescribed (which stifles innovation), there is no incentive to reduce the CI of the biofuels that comply under RFS and it lacks compliance flexibility mechanisms. In contrast, California LCFS accommodates all fuels, motivates incremental innovation towards lower CI and technological breakthroughs across the entire fuel lifecycle, provides a durable policy framework (adaptable and extendable far into the future), establishes a level playing field for higher *and* lower CI fuels alike and incorporates flexibility mechanisms, such as trading and banking of CI credits to provide least-cost compliance options for the regulated parties.

Sonia thus asserted that California LCFS is superior to RFS because it is broader-based, it is performance-based (as opposed to prescribing amounts of renewable fuels to be blended into the overall supply mix) and harnesses market forces to drive compliance efficiencies. To this end, companies can choose their compliance pathways according to their research and development strengths, competitive positioning in the market and supply assets.

Sonia further asserted the benefits of moving away from a fragmented *patchwork* of regional RFS and LCFS policies across North America towards a harmonized and *Universal* LCFS. A universal approach would help standardize measurement protocols, broaden the market of the regulated parties and the pool for trade in credits, reduce the cost of compliance, harness innovation from a larger array of companies and limit fuel shuffling. As well, a harmonized, universal approach would better facilitate the inclusion of trans-national modes of transportation and the energy they use, such as for aviation and marine fuels.

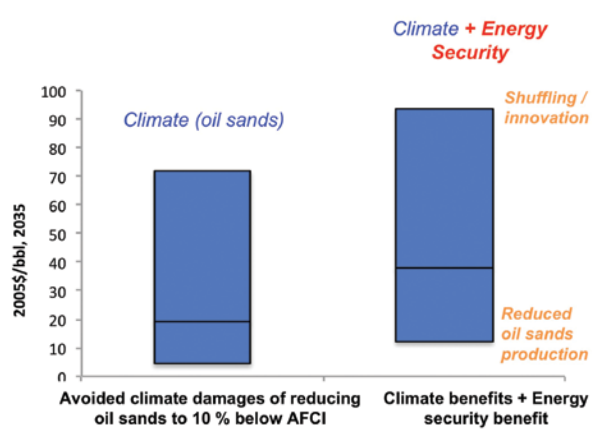
Shifting focus to the practical experience of California in implementing its LCFS, Sonia described some near-term, medium-term and long-term issues. Currently, Sonia explained, the California LCFS uses 70 default pathways to compliance with lower CI targets. Since implementation in 2011, lower CI corn ethanol has been the compliance option claimed by the regulated parties. The corresponding trade in ethanol, Sonia estimates, priced ethanol with lower CI (90.1 gCO_2/MJ) at a 10 to 20 per cent premium compared to ethanol with higher CI (98.4 gCO_2/MJ), which roughly translates to \$15-\$50/tCO_2 (Figure 11).

FIGURE 11. CALIFORNIA LCFS STATUS TO DATE (2011 IMPLEMENTATION)



Next, Sonia spoke about concerns with HCICOs - if oil sands products are shuffled away from LCFS-regulated markets, then North America will be less energy-secure. In Sonia's view, reducing *overall* oil use leads to the greatest degree of energy security. In addition, technological innovation can lead to lower CI across the HCICO product offerings, restoring domestic energy security while reducing GHG emissions (Figure 12).

FIGURE 12. CLIMATE AND ENERGY SECURITY BENEFITS DUE TO EMISSION REDUCTIONS FROM HIGH CI CRUDES



Sonia's presentation also addressed "safety valves" as a tool for regulators. RFS-based policies rely on the provision of *waivers* to mitigate compliance costs (for example, if there is a market spike in the price of ethanol). In 2010, the price of a waiver under the US RFS was \$1.58 per gallon-RIN (Renewable Identification Number), which translated into \$240/tCO_2. By comparison, the BC RLCFRR uses a safety valve of \$200/tCO_2. A research collaborative between the University of Michigan and Oak Ridge National Laboratory in the US proposes a \$300 waiver price for a national LCFS program. This would translate into a maximum of an additional \$0.34/gallon at US retail pumps (i.e., this would be the cost to consumers of industry complying with the LCFS, if implemented nationwide).

In regards to the scope of LCFS regulations in the medium-term, Sonia provided information on California's 2020 goals, which consist of a 10 per cent reduction in GHG emissions, relative to business-as-usual projections, a 3 per cent reduction in overall fuel use and increase in alternative fuel use of 3.73 billion gasoline gallons-equivalent (from 0.68 in 2007) (Figure 13). In the long term, California's goal is to reduce GHG emissions 80 per cent below 2005 levels by 2050 (Figure 14). More than half of this reduction is expected to come from the transportation sector, which even in 2050 will remain the largest source of GHG emissions in the state. Sonya explained that other sectors contribute insufficient margins on the scale of reductions needed to meet the long term targets.

FIGURE 13. CALIFORNIA'S PROJECTIONS FOR FUEL USE TO 2020

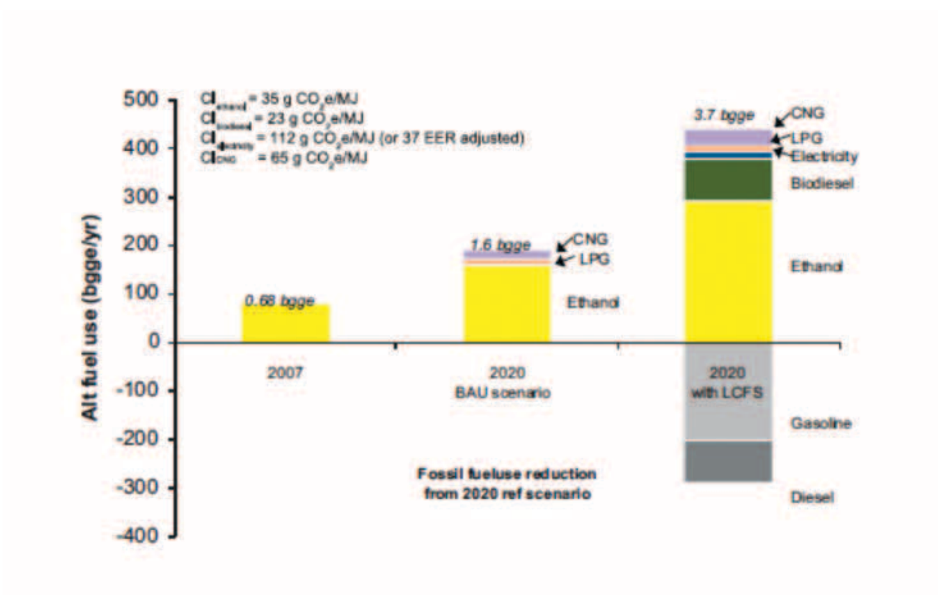
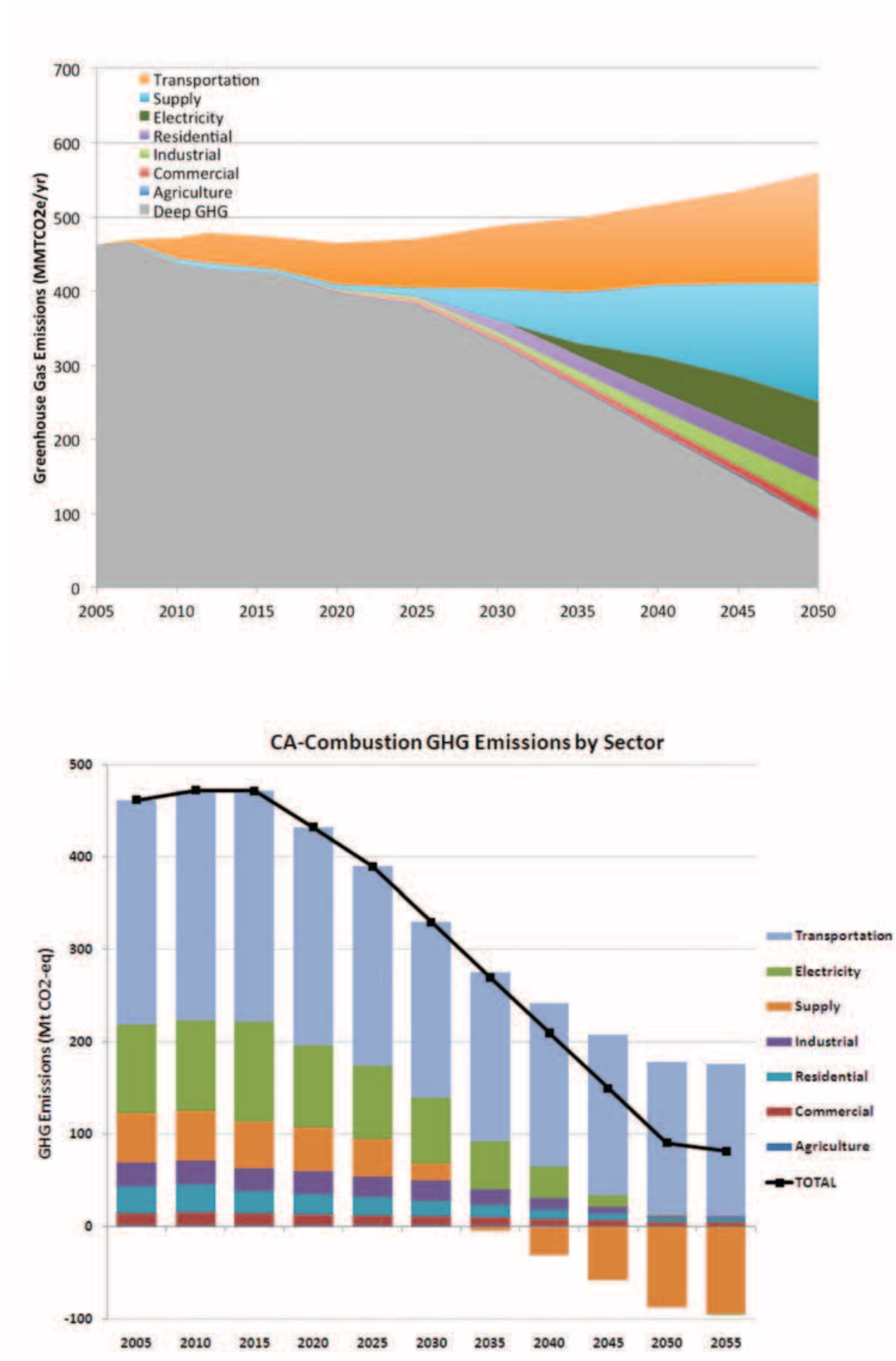
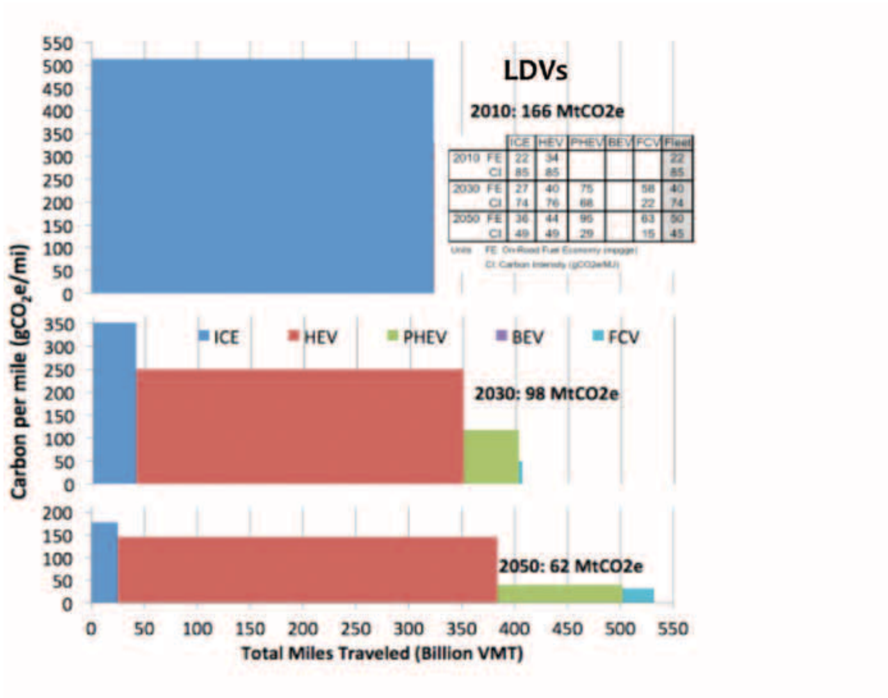


FIGURE 14. CALIFORNIA LONG-TERM GOAL: MEETING THE 2050 GOAL, 80 PER CENT GHG REDUCTION BELOW 2050 LEVEL



In the deep reductions scenario beyond 2030, Sonia forecasted substantive market penetrations of bio-based fuels in aviation, marine, rail and heavy-duty on-road vehicles; hydrogen fuels in medium-duty on-road vehicles and buses; and electricity in light-duty vehicles. As well, vehicle fuel efficiency would need to double by 2030 and improve 2.3 times by 2050, while average fuel CI would need to drop 24 per cent by 2030 and 65 per cent to meet the 2050 target (Figure 15).

FIGURE 15. CALIFORNIA'S LONG-TERM PROJECTION FOR CHANGE TO FUEL CI, VEHICLE MIX AND TOTAL GHG EMISSIONS



Sonia concluded her presentation by reiterating the need for regulatory intervention in the transportation sector to complement market-based policies aimed at reducing GHG emissions in other sectors, and that these interventions need to address vehicles, fuels and VMT in a consistent manner. While the cost of reductions will be higher in the transportation sector than in other sectors, the priority on emissions reductions in this sector necessitates action, such as the LCFS. Sonia added that the best way to reduce the initial cost of LCFS is to broaden its impact through harmonization with other jurisdictions (thus spreading the compliance cost and risk across more organizations) and, ultimately, the implementation of a Universal LCFS.

Bio notes: Bill Greenizan, Senior Advisor, Oil, Ontario Ministry of Energy

Bill Greenizan monitors market developments and advises government on issues affecting the supply, production, distribution, and pricing of oil, petroleum products and alternative transportation fuels. Bill has been with the Ministry since September 2006 and in his current role since March 2008. Prior to joining the Ministry, Bill worked in the energy marketing and trading sector at the Calgary offices of Enron, Dynegy, and Direct Energy. His various roles during this time included economic analysis, risk management, corporate finance and trading.

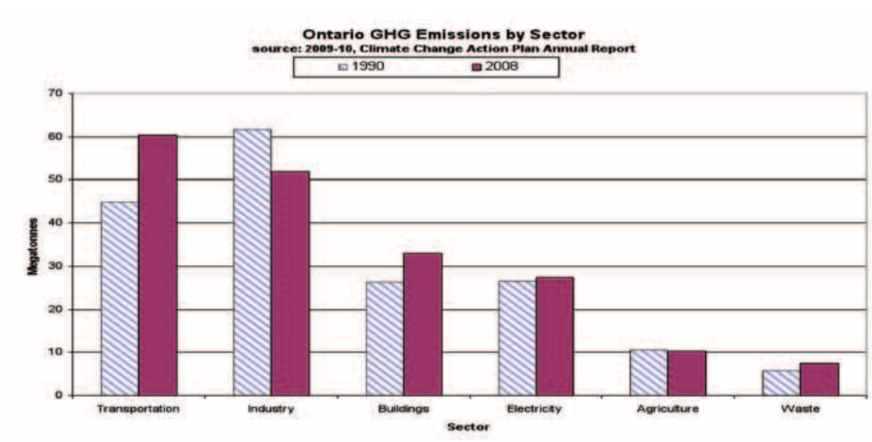
Bill is a graduate of Queen's University, holding a Bachelor of Commerce degree.

3.2 Low-Carbon Fuel Standard: Perspectives from Ontario

Bill Greenizan shared an Ontario perspective on LCFS-based regulations. Similarly to BC, Ontario has signed a Memorandum of Understanding with the State of California to coordinate efforts on the implementation of LCFS. Bill's presentation provided insight into the considerations for Ontario in implementing an LCFS.

Bill began his presentation by explaining the challenge of reducing GHG emissions in Ontario and describing the approach taken by the government. He noted that similar to BC and California, transportation activity is the largest source of GHG emissions in the province, which is growing fast, in contrast to other sectors of the economy (Figure 16).

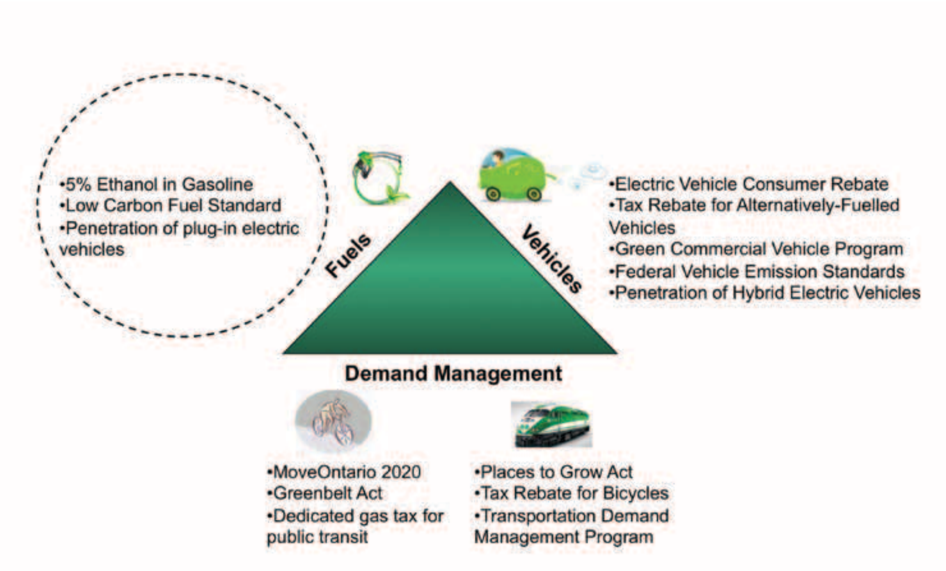
FIGURE 16. ONTARIO GHG EMISSIONS BY SECTOR IN 1990 AND 2008



Ontario has implemented a suite of policy measures to address GHG emissions in the transportation sector, focusing on vehicle technology, transportation demand management and renewable fuels. Incentives are also being used to accelerate the adoption of fuel-saving vehicle technology and design, including a consumer rebates on the purchase of EVs, and the former Green Commercial Vehicle Program, which supported the purchase of medium- and heavy-duty vehicles with advanced fuel efficiency-enhancing technologies.

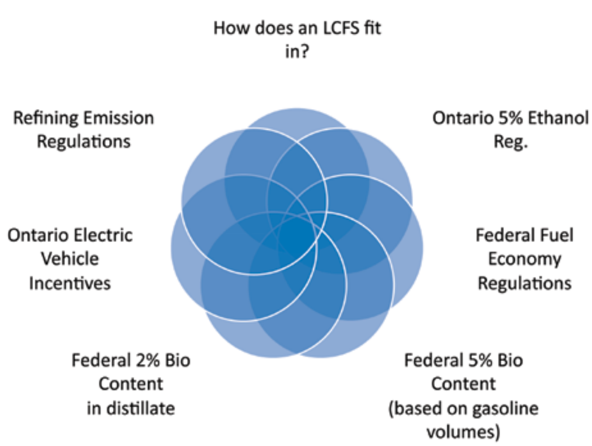
Furthermore, to moderate demand for transportation energy, Ontario has implemented the *Greenbelt Act*, and the *Places to Grow Act* that aim to concentrate urban development within existing populated centres and economic hubs and *Move Ontario 2020*, a master plan designed to enable less automobile-dependent development and more efficient freight movement throughout the Greater Toronto and Hamilton areas. On fuels, Ontario has mandated the blending of ethanol into gasoline to an average of 5 per cent and is considering options to invest in public charging infrastructure to support EV use. Bill added that CNG is also fuel tax-exempt in Ontario (Figure 17).

FIGURE 17. TRANSPORTATION ENERGY USE, EMISSIONS AND REPRESENTATIVE POLICIES IN ONTARIO



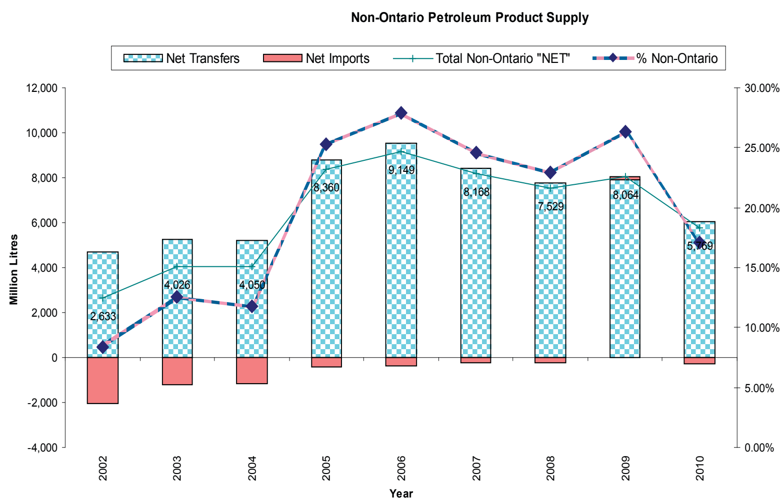
Bill explained that LCFS in Ontario must be viewed through three policy "lenses": economic development (particularly from a rural perspective), energy security (for which ethanol blending enhances options to draw on fuels from local sources) and environment (lifecycle GHG emissions reductions, in particular). Bill noted that LCA can be complex tool, requiring special skills and literacy to ensure that inputs are validated and data quality is sufficient for regulation. Boundary conditions and accurate treatment of co-products are also critical for proper regulatory management. Bill cautioned not to underestimate the challenge for policymakers and regulators to fairly and objectively compare and contrast fuel-and-technology options over their respective lifecycles. Ontario's experience in trying to promote fuel-switching from gasoline to CNG offers a lesson. Limited access to CNG fuelling infrastructure lowered consumer interest, leading to fewer CNG vehicle models marketed by automakers, which in turn undermined investment in fuelling infrastructure – and so the vicious circle continued (Figure 18).

FIGURE 18. TRANSPORTATION POLICIES IN ONTARIO



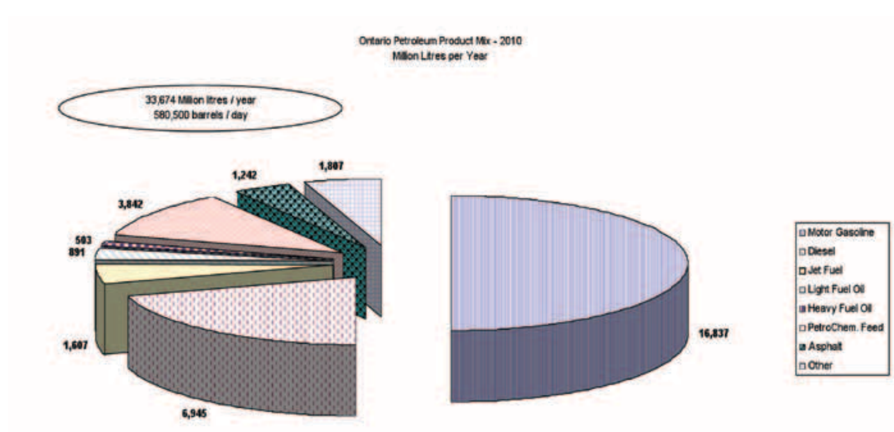
Remarking that the majority of the lifecycle GHG emissions associated with the current use of fuels in Ontario occurs during the tank-to-wheels stage, which is highly sensitive to fuel efficiency, and that GHG emissions would not decrease as long as the demand for transportation energy increases at its current rate, Bill wondered how LCFS would fit into the current array of policies. He explained that transportation provides for critical services, including public safety, healthcare, telecommunications and food delivery. The design of LCFS must consider the impacts on these critical elements of public policy. Bill also noted that Ontario is highly reliant on fuel imports to meet the demands of its transportation system (Figure 19).

FIGURE 19. ONTARIO RELIANCE ON PETROLEUM PRODUCT IMPORTS



The share of demand for various petroleum products in Ontario was presented in Figure 20, showing that gasoline and diesel constitute the bulk demand, but demand for petrochemical inputs to product manufacturing systems are also significant, especially for asphalt production.

FIGURE 20. ONTARIO PETROLEUM PRODUCT DEMAND IN 2010 (MILLION LITRE PER YEAR)



The output of Ontario's refineries is oriented towards the demand mix for petroleum products in the province, but it also relies on a range of crude product inputs from around the world, including Western Canada (Figure 21). Heavier crude oil inputs, Bill expects, would probably constitute the primary input to asphalt production (Figure 22). The demand for non-energy products, therefore, is a constraint on refinery operations that must also be considered under LCFS.

FIGURE 21. ONTARIO REFINERY CRUDE OIL RUNS

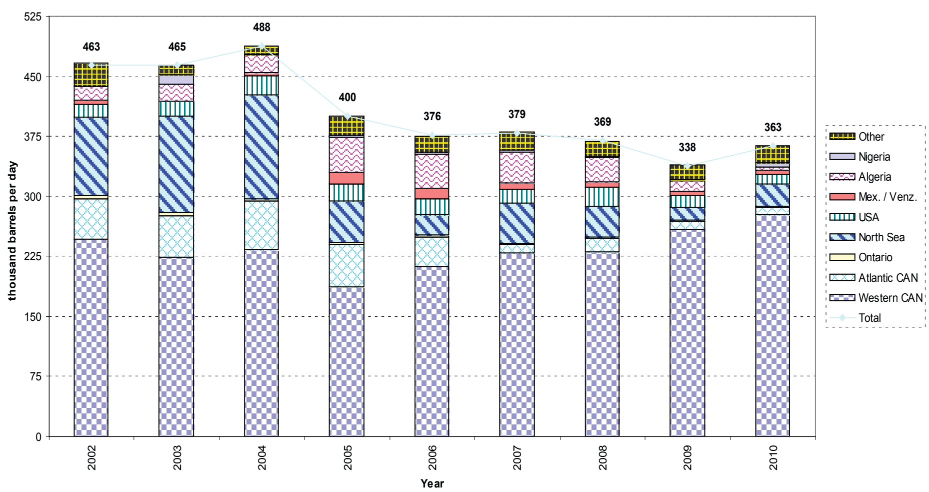
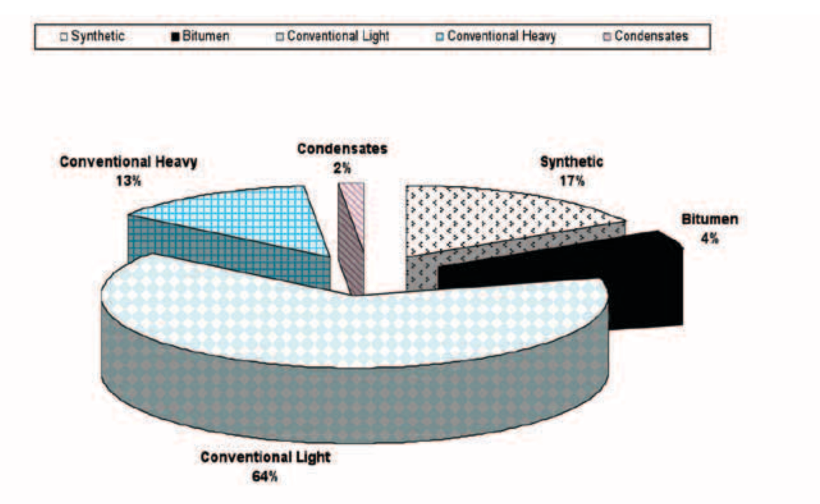


FIGURE 22. ONTARIO PROCESSED CRUDE OIL TYPES IN 2010



Bill concluded his presentation by questioning how LCFS might be considered under international trade laws, noting that the recent changes to RFS in the US, which require limits on the CI of renewable fuels, was challenged by the Brazilian sugarcane industry. More challenges can be expected if such policies are perceived to favour domestic operations. "No policy exists in a vacuum", said Bill, and recommended that careful thought be given to the potential unintended consequences of implementing LCFS in Ontario.

Bio notes: James P. Uihlein, Fuels Technology Advisor, Downstream & Chemicals, Chevron

James P. (Jim) Uihlein is a Fuels Technology Advisor for Chevron Downstream & Chemicals, responsible for fuels regulatory development with a focus on California. He has participated in the development and implementation of the California LCFS regulations from the beginning of the program, both internally to Chevron and as Chair of the Western States Petroleum Association (WSPA) LCFS Policy Development Group.

Jim has more than 31 years of experience in the Refining Industry, the majority of which has been spent on a variety of Fuels Technology issues from production processes and formulation to fuel-vehicle interactions and regulatory development.

3.3 BC's Opportunities to Profit from California's Experience

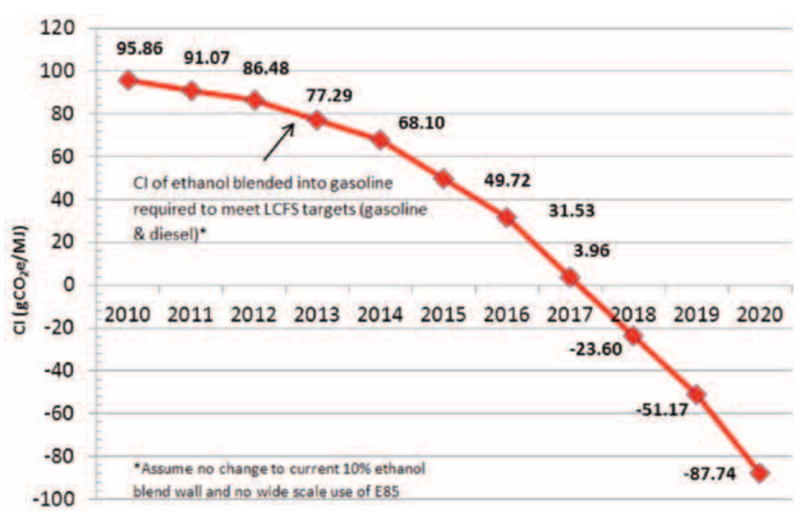
Jim Uihlein reflected on the experience of designing and implementing the California LCFS, and identified aspects that should be emulated in BC, as well as those for which improvements are warranted.

Jim began by assessing the useful aspects of the California LCFS:

- Lookup tables for CI values;
- Ensures consistency;
- Simplifies reporting;
- Supported by a clear process for updating the values (changes are already being proposed to streamline the process);
- Separates gasoline and diesel into two compliance pools, but operates as one program that permits credits transfer between pools;
- Indirect Land Use Changes (iLUC) are recognized as real factors, but there is uncertainty about how to integrate their impacts into CI values.

Jim explained that exclusion of iLUC in the early years of RLCRRS compliance in BC could lead to misdirected investments and stranded capital, particularly if its eventual inclusion renders biofuel a less effective compliance strategy than expected. This consideration bridged to the aspects of the California LCFS that Jim advised BC to consider as challenges. First and foremost, no demonstrable compliance pathway currently exists to meet the 2020 targets under the BC RLCFRR. Jim noted that compliance is not simply a matter of scaling up existing CI reduction strategies, but it requires entirely new technologies, available in sufficient quantities and viable in terms of consumer acceptance and supporting infrastructure.

FIGURE 23. CALIFORNIA LCFS COMPLIANCE SCHEDULE



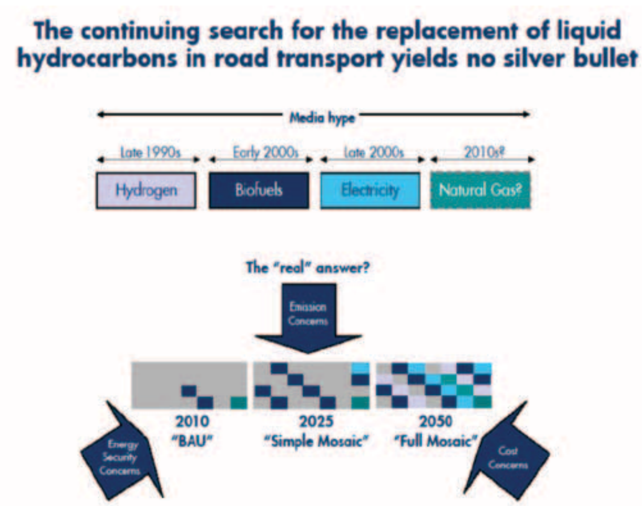
Jim noted that while blending E10 is an effective way to meet the California LCFS targets today, it will not be sufficient for compliance in 2015; neither will the sugarcane-derived ethanol (Figure 23). Alternatives, such as non-biomass-derived fuels, natural gas and electricity for vehicles will have to be pursued. However, barriers to the availability and serviceability of these new vehicles exist.

3.4 Shell's Low-Carbon Framework for Road Transportation Fuels

Gerry Ertel shared the perspectives of Shell Canada on biofuels and low-carbon fuels, as well as Shell's experience with BC's RLCFRR. He also presented a comprehensive policy framework, called the *Low Carbon Framework for Road Transportation Fuels*, as an alternative to the LCFS approach.

Gerry began by framing Shell's involvement in the alternative fuels marketplace, which spans 30 years of development and investment in biofuels, including the infrastructure for storage, blending and distribution (Figure 24). Currently, Shell is one the world's largest provider of biofuels, distributing nine billion litres in 2009 and buying increasing volumes of ethanol for gasoline and FAME (fatty acid methyl esters) for diesel. Shell will further add two billion Litres in low CO_2 sugar cane ethanol production capacity through a joint venture with Cosan, valued at $12 billion.

FIGURE 24. PATTERN OF ENERGY TECHNOLOGY ADOPTION OVER TIME



Gerry explained that Shell will continue to build its capacity in biofuels that provide the best combination of performance and low well-to-wheel CI characteristics from more sustainable feedstocks. Gerry explained that "next generation" biofuels (e.g., ethanol produced from plant cellulose instead of plant starches and sugars, thus having a very low CI), offer the potential for further improvements in net CI emissions.

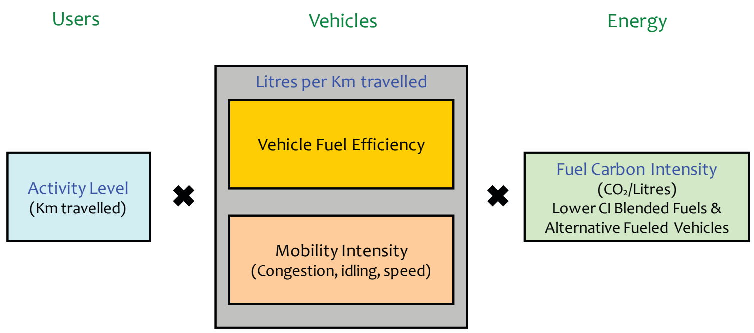
This is a more realistic commercial solution to progressively reducing CI of the transport fuels sector in the next 20 years. Gerry warned, however, that there are physical limits to the rate at which new energy technologies can be deployed and that changing energy technology takes time. He asserted that fossil fuels will likely remain a dominant transportation fuel source, until at least the middle of the century, with biofuels the only material low-carbon option during the next 10 to 15 years.

Bio notes: Gerry Ertel, Regulatory Affairs Manager, Shell Canada

Gerry Ertel assumed the role of Regulatory Affairs Manager for Shell Canada Limited in September 2007. In this position Gerry has the lead responsibility for the management of climate change policy issues as they relate to Shell businesses operated in Canada, including oil sands facilities, refineries, gas plants and chemical plants. Gerry also manages the broad range of federal, provincial and regional government emerging policy issues for Heavy Oil and Onshore Gas, including cumulative effects, air quality, water use and quality, reclamation, land use, infrastructure, etc. Gerry graduated from the University of Waterloo in 1976 with a degree in Chemical Engineering.

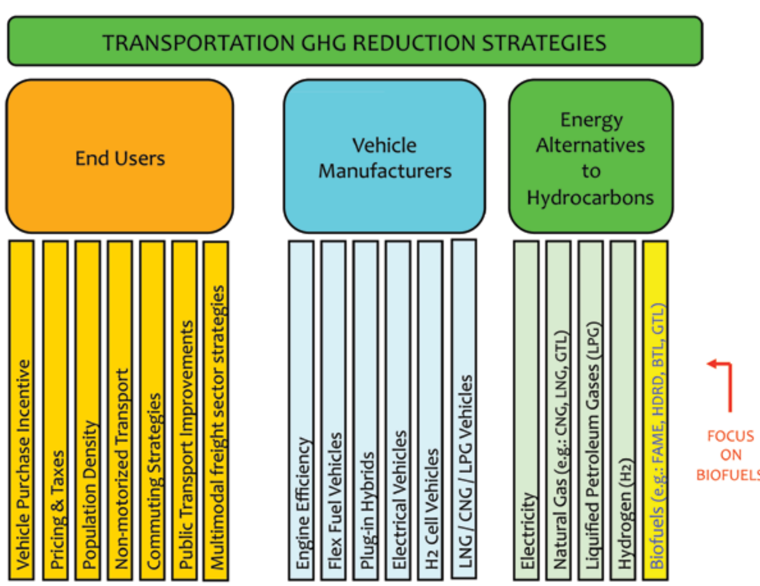
Gerry noted that in the meantime, policymakers have several factors to consider, in addition to fuels to successfully reduce GHG emissions from the transportation sector. These factors can be grouped under *users*, *vehicles* and *energy*, each being part of an integrated system (Figure 25). The groupings map to a variety of strategies, as shown in the inset image. Gerry stressed that changes pursued under one group must complement changes in another group; otherwise, the policies tend to become unworkable.

FIGURE 25. FACTORS GOVERNING TRANSPORTATION GHG EMISSIONS



Gerry asserted that Shell supports regulations to address GHG emissions, and that an economy-wide carbon price will be inadequate to motivate change in the transportation sector (Figure 26). However, the BC RLCFRR is an alternative energy regulation that, to achieve compliance, requires new vehicle technologies that are beyond the control of the fuel suppliers. Also, the fuel shuffling that can occur as an unintended consequence of implementing LCFS in a small jurisdiction makes the policy inefficient and costly. For similar reasons, trading of credits among the regulated parties is unrealistic in a small market like BC. Gerry cautioned that when exiting the market in a regulated jurisdiction becomes a reasonable compliance option for a major company, there is a problem with the regulation. Compliance with a *market*, as opposed to compliance within a political *jurisdiction*, is a better option.

FIGURE 26. LOW CARBON FRAMEWORK FOR ROAD TRANSPORTATION FUELS (LCFRTF)



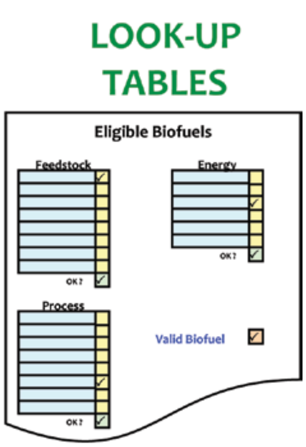
The requirements of a regulation must be placed on parties that have the capacity to respond. Under LCFS, shifting away from fossil fuels is viewed as the fossil fuel supplier's responsibility, despite the fact that alternative fuels (e.g., CNG, LNG, LPG, H_2 and electricity) depend on the presence of alternatively-fuelled vehicles and the building of different fuel distribution networks, not to mention consumer preference for the alternatives. Gerry advised that the growth of alternative fuels should be managed through a separate set of regulations that also encourage the development of alternatively-fuelled vehicles and infrastructure. This would preserve consumer choice within a market of various mobility options. Until such time as these options are available, currently available biofuels are the best option for fossil fuel suppliers to use to reduce the carbon intensity of their products.

As an alternative to LCFS, Gerry then introduced Shell's Low Carbon Framework for Road Transportation Fuels (LCFRTF). The framework is comprised of the following basic assumptions and attributes:

- The volumetric approach of RFS and LCFS misses the opportunity to focus and optimize on GHG emissions reduction.
- RLCFRR and the California LCFS are "off fossil fuels" programs with inadequate compliance options.
- LCFRTF, on the other hand, bridges between these positions and provides a biofuels regulation focused on CI and on GHG emissions reduction, incenting more advanced biofuels to enter the market.
- LCFRTF proposes an evolution from volume-based regulations with increasing CI targets that tracks advances in technology and LCA.
- LCFRTF optimizes biofuel GHG emissions reduction while maximizing their use.
- LCFRTF provides viable, affordable compliance options. Fuel quality is never jeopardized. The blend-wall constraints of RFS may also be avoided.
- When possible, the LCFRTF should incorporate "sustainability" criteria to ensure that biofuel benefits are not eroded. Shell has voluntarily adopted this principle.
- Ideally, LCFRTF should constitute a national biofuels regulation. It reflects Shell's vision of a global approach to managing GHG emissions from transportation energy use.

The elements of the LCFRTF move progressively from lookup tables as a starting point in time (Figure 27), to buckets of proven, incremental fuels and technologies, and finally arriving at a more granular array of fuel options based on mature LCA, technology and fuel availability.

FIGURE 27. ELEMENTS OF LCFRTF



According to Gerry, the LCFRFT approach progressively reduces the CI of the transportation fossil fuel pool via substitution with lower CI biofuels, places regulatory requirements on parties that have the capability to act now, focuses on real GHG reductions rather than strict volume mandates and facilitates a gradual migration to a CI reduction mandate. Gerry presented a table on the advantages of starting with a lookup table approach (similar to a conventional volumetric RFS approach), as well as the disadvantages.

Advantages

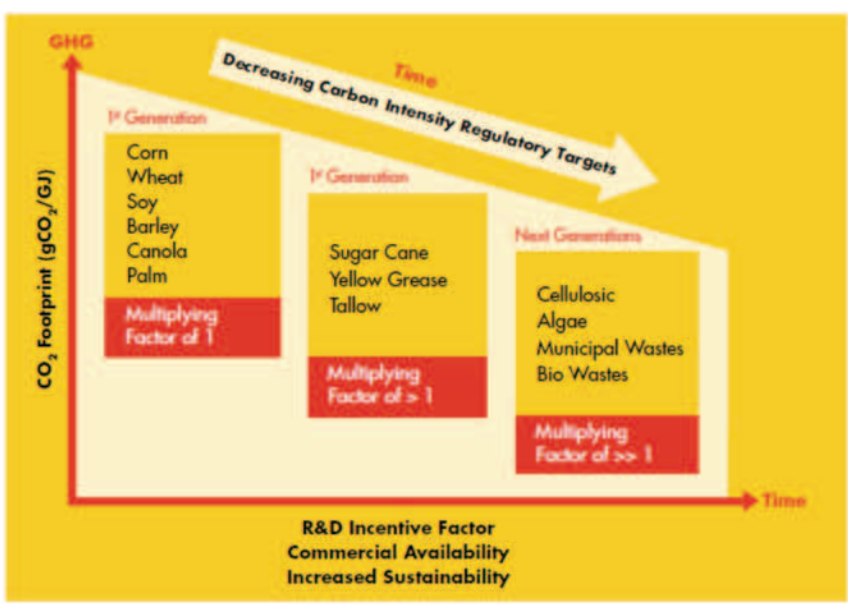
- **Simple regulation**
  - Conventional measurements
- **Simple regulatory reporting**
  - Pool average
- **Favours biofuels' growth**
  - Agricultural demand
  - New biofuel industry
  - Job creation
- **Straightforward subsidies**
  - Volume based
- **Incentivisation**
  - Multiplying factors

Disadvantages

- **No sustainability certainty**
  - Food vs. Fuel debate
  - Water usage
  - Biomass sourcing
- **No GHG reduction certainty**
  - All biofuels considered equal
  - Close to conventional HC
- **Technical limitations**
  - Fuel performance
  - OEM's limitations
  - Legacy vehicles
  - Favours boutique fuels
  - Weather challenges

The next phase is the bucket approach, which is similar in many respects to what Gerry called a "smart" renewable fuels framework (Figure 28).

FIGURE 28. LCFRTF INITIAL BUCKET APPROACH



Advantages

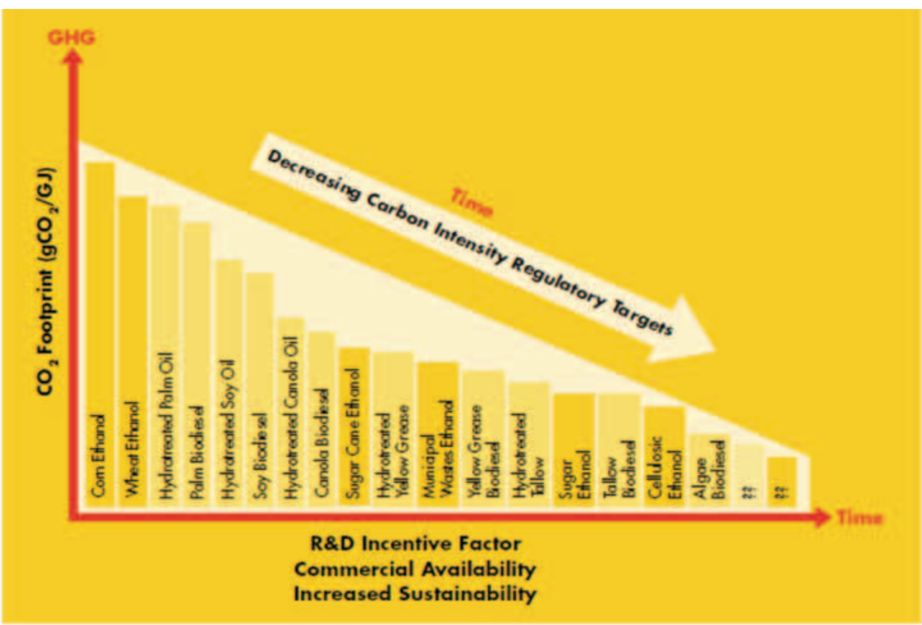
- **Gradual transition**
  - Biofuels grouping
  - In-sync with LCA science
  - Avoids volume/CI double role
  - Flexibility to fuel providers
- **Reduces technical limitations**
  - In-sync with engine technology
  - Delays the volume blend-wall
  - Increased biofuel compatibility
- **Targets GHG emissions**
  - CO_2 reduction vs. volume
  - Gradual CI reduction targets
  - Measurable GHG reductions
  - Biofuels GHG recognition
  - Increased energy conservation

Disadvantages

- **Regulatory complexity**
  - Volume based ➔ CI based
  - Different energy intensities
  - Different energy values
  - Different biofuel technologies
- **Reporting complexity**
  - Single Fuel Pool
  - Weighted average CI
- **Supply-chain complexity**
  - Biofuel sourcing
  - Biofuel certification
  - Biofuel pooling

The final phase is the granular approach under Shell's smart renewable fuels framework (Figure 29).

FIGURE 29. LCFRTF FULLY IMPLEMENTED, GRANULAR APPROACH



Advantages

- **Maturity**
  - Mature LCA science
  - Individual CO_2 footprint
  - Maximum flexibility
  - Market-based differentiation
  - In-sync with sustainability
  - In-sync with engine technology
- **Targets GHG emissions**
  - Full GHG recognition
  - Measurable GHG reductions
  - Consistent CI reduction targets
- **Technology developments**
  - Continuous improvements

Disadvantages

- **Regulatory complexity**
  - Multiple biofuels
- **Reporting complexity**
  - Single Fuel Pool
  - Weighted average CI
- **Supply-chain complexity**
  - Biofuel sourcing
  - Biofuel certification
  - Biofuel pooling

To add some specifics in terms of timing and to summarize the key attributes of the LCFRTF, Gerry presented Table 2.

TABLE 2. SUMMARY OF KEY POSITIVE AND NEGATIVE ATTRIBUTES OF THE LCFRTF GHG EMISSIONS REDUCTION APPROACH

APPROACH	SCOPE	POSITIVES	NEGATIVES	TIME
LOOK-UP TABLES	Validation of biofuels based on generally accepted principles	User Friendly Amended easily Simple Regulatory Reporting Possibility of Multiplying Factor Favours Simple Regulations	No GHG Recognition Variable Environmental Benefits Does not favour CI reduction	2010 - 2015
BUCKET	Grouping of biofuels based on feedstock and manufacturing processes	Partial GHG Recognition R&D Incentive Factor Partial differentiation Increased Sustainability Proof Gradual CI reduction	Complex Supply-Chain Complex Regulatory Reporting	2012 - 2020
GRANULAR	Differentiation of biofuels based on their individual CO_2 footprint	Full GHG Recognition Market-Based differentiation Sustainability Certificate Firm CI reduction Established Biofuels Markets	Detailed LCA Modelling Complex Supply-Chain Complex Regulatory Reporting	2015 - 2025

Gerry concluded with recommendations to avoid further amendments to the current LCFS, and instead shift to a regulatory approach that achieves GHG emissions reductions with viable and affordable compliance options, and which creates a stable and certain investment climate. Gerry repeated that “off fossil fuel” mandates should be addressed with policies that focus on EVs and other alternatively-fuelled vehicles, such that the regulated parties that have direct control over the technology and infrastructure are motivated and enabled. Gerry further advised BC to shift to Shell’s LCFRTF, or to consider harmonizing with the Alberta RFS, thus initiating a “western coalition” that could expand across Canada. Gerry also noted that the sustainability of biofuel feedstocks is important to investigate, but it will not easily be incorporated into fuel regulations, so new ways of addressing this issue must be sought.

Shell is convinced its LCFRTF approach to biofuel policy strikes a good balance across the interests of all parties, and brings focus back to the priority of delivering real GHG emissions reductions. Shell also believes that the LCFRTF has the GHG focus of an LCFS-type approach, and the simplicity and practicality of an RFS-style regulation. Gerry admitted that the plan is long term, but all plans need to start with an idea around which consensus can be built.

3.5 Assessing Low-Carbon Fuel Standards and Other Policy Frameworks: The Case for Biofuels

Doug Hooper provided an economic and environmental context in which to consider policies that sustain and expand the use of biofuels, focusing on the LCFS as well as other policies in Canada, and the improvements that are needed.

Doug began by reviewing the history of the Canadian Renewable Fuels Association (CRFA). The CRFA was founded in 1984 as a non-profit organization with a mission to promote renewable fuels for transportation through consumer awareness and government liaison activities. The CRFA membership is composed of representatives from all levels of the ethanol and biodiesel industry, including grain and cellulose ethanol producers, biodiesel producers, agricultural companies and associations and technology developers.

Next, Doug provided an overview of the prevailing federal and provincial mandates on biofuels (Figure 30). He pointed out that these mandates are complemented by programs to support the biofuels industry, including the $1.5B ecoENERGY for Biofuels Program, which subsidizes biofuels production; the $200M ecoABC Program, which incents agriculture producers to participate in expansion of ethanol and biodiesel production; SDTC's $500M Next Gen Biofuels Program, which grants capital to commercialize advanced biofuel production processes and technologies; and various production incentives and tax exemptions at the provincial levels.

FIGURE 30. FEDERAL AND PROVINCIAL MANDATES FOR SUPPORTING RENEWABLE FUEL USE

Federal Mandates
5% Ethanol in gasoline (December 15, 2010)
2% Biodiesel in diesel (July 1, 2011)

Provincial Mandates

Province	Ethanol	Biodiesel
British Columbia	5%	4% / 5% (2011/12)
Alberta	5%	2%
Saskatchewan	7.5%	2%- July 1, 2012
Manitoba	8.5%	2%
Ontario	5%	

Bio notes: Doug Hooper, Chair of the Government Affairs Committee, Canadian Renewable Fuels Association

Doug Hooper is the Chair of the Government Affairs Committee, Canadian Renewable Fuels Association (CRFA). In 2010, Doug was Chair of the CRFA and conference chair of the 2009 Canadian Renewable Fuels Summit held in Vancouver, BC. The CRFA is an industry-led association that works to promote and advance the use of renewable fuels for transportation in Canada.

Since 2005, Doug has been the CEO of Canadian Bioenergy Corporation, one of Canada's leading biodiesel and bioenergy project development companies.

Doug then described the economic contribution of the renewable fuel industry to Canada. Currently, there are 28 renewable fuel production plants operating in Canada, with capacity to produce 1.8B litres of ethanol and 200M litres of biodiesel (Figure 31). By contrast, the capacity needed to comply with the federal RFS, described above, is 2.5B litres and 600M litres of ethanol and biodiesel, respectively. According to the CFRA, 14,000 direct and indirect jobs are created in the construction of new production facilities. More than 1,000 permanent manufacturing jobs have been created by the Canada's biofuels industry. In terms of capital investment, economic activity and tax revenues, federal and provincial, the industry contributes $2B annually to Canada's economy.

FIGURE 31. CANADIAN RENEWABLE FUEL PRODUCTION

Doug explained that renewable fuels can cut transportation sector GHG emissions considerably, up to 62 per cent with corn-based ethanol, and 83 per cent and 99 per cent using biodiesel made from canola and waste fats, respectively. Due to their low-carbon signature, Doug asserts that biofuels are a cornerstone of any low-carbon policy. He further reinforced that biofuels are a market-ready means of addressing the confluence of limited oil reserves and increasing global energy demand, driven in part by the economic growth of Asia. Doug cited an International Energy Agency technology roadmap for transport,[7] which states that biofuels will provide 27 per cent of global transport fuel by 2050, displacing 2.1 billion tonnes of CO_2 from the combustion of gasoline – *without* compromising global food security.

However, reducing GHG emissions is not the only regulatory issue for governments to consider. Doug noted that criteria air contaminants, water quantity and quality, land use (direct and indirect), economic growth and jobs, as well as energy security and fuel diversity, are all important issues in which biofuels play a role.

7 Source: **http://www.iea.org/papers/2011/Biofuels_Roadmap.pdf**

Key priorities of transportation fuels policy, according to Doug, should be:

1. Ensuring market access

- via RFS
- via LCFS

2. Ensuring GHG emissions reductions

- via LCFS
- via CI thresholds (e.g., US RFS2, EU-RED, and Alberta)

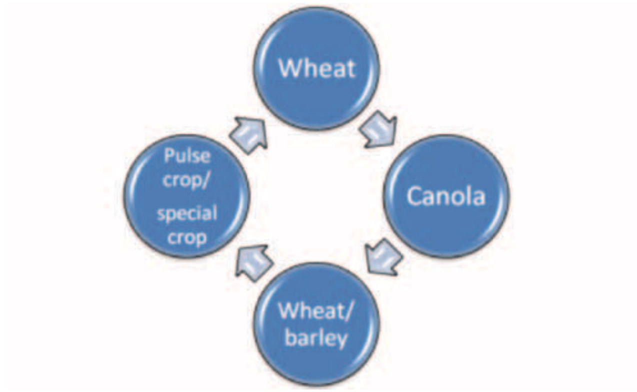
3. Ensuring sustainability

- via land use verification (e.g., US EPA, EU-RED)
- via industry standardization (e.g., ISO)

Taking canola farming in Canada as an example, Doug identified sustainability benefits of biofuel feedstock production; namely, moisture conservation in the soil due to crop rotation, which allows for carbon build-up in the soil, disease management, reduced use of fertilizer and conservation of fallow acres. Doug further explained that to promote these sustainable outcomes, the principles of biofuel policy should include:

- Feedstock neutrality
- Technology neutrality
- Fair and comparable baselines between fossil fuels and renewable fuels
- Market-based and comparable baselines between fossil fuels and renewable fuels
- Market-based policy (investment capital will choose the most competitive industrial model)
- Avoid stranding existing assets (can be done by grandfathering and ramping-up policy implementation, as opposed to dismantling)
- Harmonize to the highest standards
- Transparency (requires CI accounting for baseline fuels)
- Efficiency (the policy must have simple compliance rules, easily enforced)
- Effective (requires the elimination of "off-ramps" and other complexities, as well as penalties to assure compliance, as opposed instruments that permit avoidance)
- Implementation should be timely (soon) and fair (be sure to follow-through) and not subject to frequent review and revision (5 year review reasonable)

FIGURE 32. SUSTAINABLE BIOFUEL FEEDSTOCK CROP ROTATION



Doug reflected on BC's experience with its Renewable Fuel Requirements Regulation (RFRR), which proved simple and easy to implement and enforce compliance (Doug stated that industry exceeded the requirements by approximately 10 per cent) and which saved consumers more than $80M at the pumps in BC. Moving forward with the RLCFRR in BC, Doug predicted that existing biofuels could contribute 2 per cent (in addition to current levels) of the CI reduction by 2014 and 3 per cent by 2020. He further observed that Canadian-produced biofuels have lower CI values than in the US, which should help to grow demand for domestic supply.

Doug also noted that a significant opportunity exists in sourcing ligno-cellulosic ethanol from the Mountain Pine Beetle kill in BC's forests, and growing markets for high-blend biofuels (e.g., E85 and B20) for the 60,000 vehicles in the province that are Flex-Fuel ready. In Doug's view, the RLCFRR can further contribute to BC's prosperity since biofuels can be locally sourced and their production develops new jobs in an innovative clean energy sector, improves air quality and positions BC at the leading edge of an advanced biofuels industry globally. To realize these economic benefits, Doug recommended to expand the RLCFRR and to complement it with additional support for high-blend biofuel supplies, by offering grandfather provisions for existing facilities and investments. To this end, creating a competitive investment climate to attract capital in the production of advanced biofuels is critical. Doug provided a list of the following measures, which could be considered to achieve this:

- Financial support for technology development via demonstration-scale facilities where advanced technologies can be tested and developed
- Loan guarantees and refundable capital grants
- Accelerated capital cost allowances
- Tax credits on production to stimulate the initial phase of advanced biofuels development
- Exemptions on excise and carbon taxes for biofuel producers

Doug concluded his presentation by stating that although bio-chemical and thermo-chemical processes of biofuels production face technical challenges, Canadian innovators have made major breakthroughs towards driving down the cost of these technologies. Additional financing may be required to support the building of infrastructure for the collection, storage and distribution of feedstock (input) and product (output) for the next generation of advanced biofuels facilities. Standards for automakers are also need to accommodate widespread use of high-blend fuels (e.g., E15, E85, B5-B20 and B100).

3.6 Assessing the Low-Carbon Fuel Standard

Dr. Stern completed the roster of speakers in this session with an assessment of the impacts and implications of LCFS, according to a set of policy principles that underpin, from the perspective of ExxonMobil, effective climate change policy design. He articulated some of the challenges in complying with LCFS-based regulations in California and BC and proposed alternative approaches.

David began his presentation with a concise list of principles against which to assess policies aimed at managing GHG emissions:

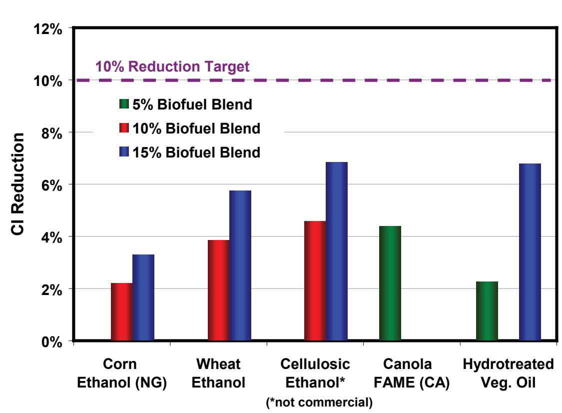
- Ensure a uniform and predictable cost of GHG emissions across the economy
- Let market prices drive the selection of solutions
- Promote global participation
- Recognize the priorities of the developing world
- Limit consequences of differing national policies on competitiveness
- Minimize complexity to reduce administrative costs
- Maximize transparency to companies and to consumers
- Adjust, in the future, to developments in climate science and the economic impacts of climate policies

David then proposed an axiom that climate policy should seek to minimize the overall cost to society of reducing climate risks.

Referring, as did other presenters, to the bulk of GHG emissions occurring during the tank-to-wheel phase of a fuel's lifecycle (~78 per cent according to CARB), David asserted that the LCFS mandate to reduce the CI of transportation fuels by 10 per cent was not feasible without large numbers of EVs in use and substantive use of low CI biofuels (Figure 33).

David questioned whether even E85 could deliver compliance with the 10 per cent target under the California LCFS by 2020 and cautioned that this is not feasible with corn-based ethanol. To this end, David explained that either the production of Brazilian sugarcane ethanol would need to increase 10 fold from the 2008/9 production level, or the production of cellulosic ethanol would need to be double the US RFS2 mandate for the LCFS target to be met. To use E85 in order to meet the 10 per cent target, the US would need to increase its production 1,000 times from today's levels (to 21 billion gallons per year). Moreover, 100 million flexible-fuel vehicles, compared to the 6 million on the road today, and 60,000 E85 stations, compared to the 2,000 existing in the US today, would need to be added.

FIGURE 33. BIOFUEL BLEND CIS

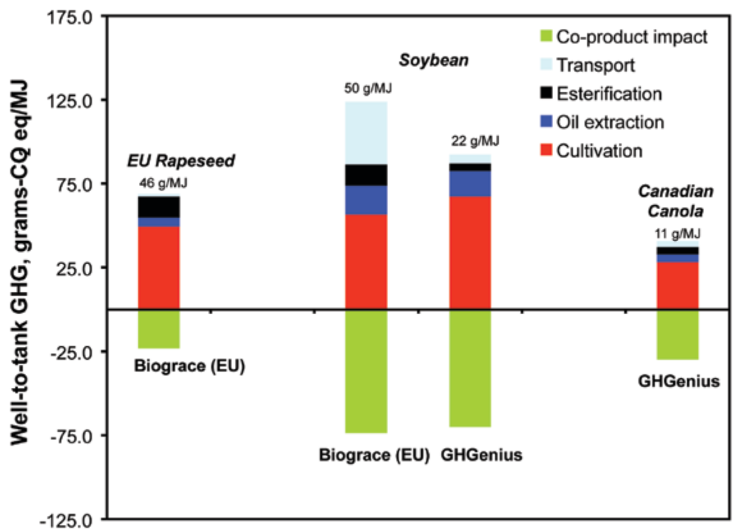


Bio notes: Dr. David Stern, Advanced Fuels Senior Advisor, ExxonMobil Refining and Supply Company

Dr. David Stern is currently the Advanced Fuels Senior Advisor at ExxonMobil Refining and Supply Company. He has 20 years of R&D experience in the petrochemical, refining and catalyst manufacturing industries. David's previous technical contributions focus on the discovery, applications and development/ commercialization of new materials and processes for chemicals synthesis and refining applications. Areas of expertise include selective aromatic transformations, lube hydroisomerization, environmental catalysis, light alkane upgrading, Fluid Catalytic Cracking (FCC) and reforming. David managed R&D in catalyst development and manufacture, hydroprocessing, advanced separations, process development, and the discovery of materials and catalytic processes. David holds more than 60 patents, and has authored more than 35 technical publications. He holds a Ph. D. in Chemistry from Northwestern University.

Next, David discussed the caveats of the LCA modeling used to determine the net GHG impact of both fossil fuels and biofuels. David reviewed the factors used in LCA modeling for canola/ rapeseed, and soybean, FAME biodiesel in both Europe and BC (Figure 34). David pointed to large CI differences, even for the same FAME biodiesel, in these two jurisdictions and questioned whether the LCA models being used in these jurisdictions are technically sound enough to accurately determine the CI reduction of these biofuels.

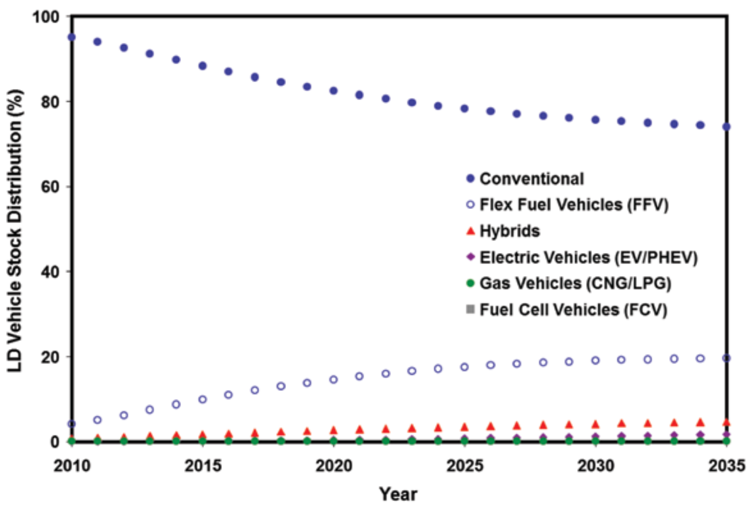
FIGURE 34. WELL-TO-TANK LCA OF BIODIESEL



Another aspect of the LCFS that David focused on was the unintended consequences of differentiating CI for crude oil. Canada is the largest exporter of crude oil to the US (EIA, October 2010). For jurisdictions where LCFS is implemented, the export of Canadian oil sands crude to those jurisdictions may be impacted if a higher CI value is applied. David pointed out that this may result in the "shuffling" of high CI crudes, which could increase GHG emissions, as the crude may be shipped to other markets instead of being transported to the US via pipeline. This would result in higher transportation-related emissions globally (up to 2 times according to the *Barr Study: Low Carbon Fuel Standard "Crude Shuffling" Greenhouse Gas Impacts Analysis*, June 2010). David suggested that petroleum production-related GHG emissions are, therefore, perhaps more effectively regulated at the source (i.e., as manufacturing sector emissions) than through the LCFS.

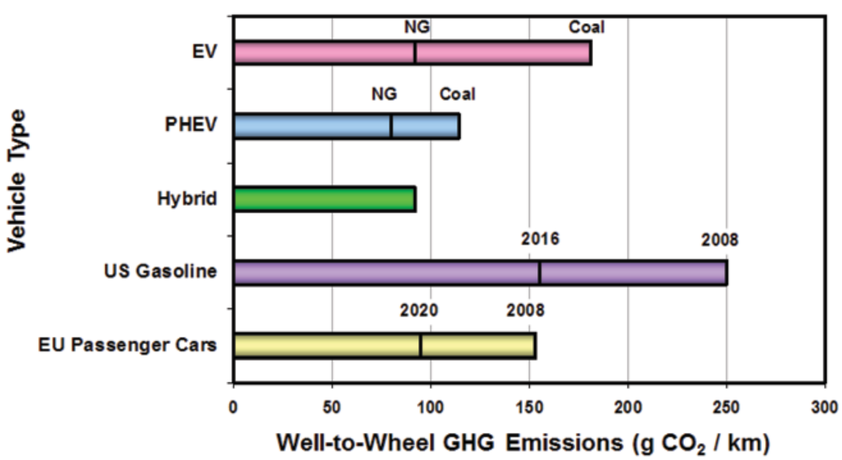
In order to assess the use of alternative fuel vehicles (electric, CNG and fuel cell-powered vehicles) to meet the LCFS, David reviewed the projections for light-duty vehicle stock in the US by fuel type and powertrain (EIA 2011 Vehicle Projections), shown in Figure 35. David explained that the fraction of vehicles required for a 10 per cent reduction in CI by 2010, according to the BC Energy & Mines RLCFRR Intentions Paper, is 30 per cent CNG-powered, or 12 per cent EVs. This fraction of vehicles is much higher than that anticipated by the EIA vehicle projections for the US.

FIGURE 35. MARKET PENETRATION OF LOW-CARBON FUEL-POWERED VEHICLES IN THE US



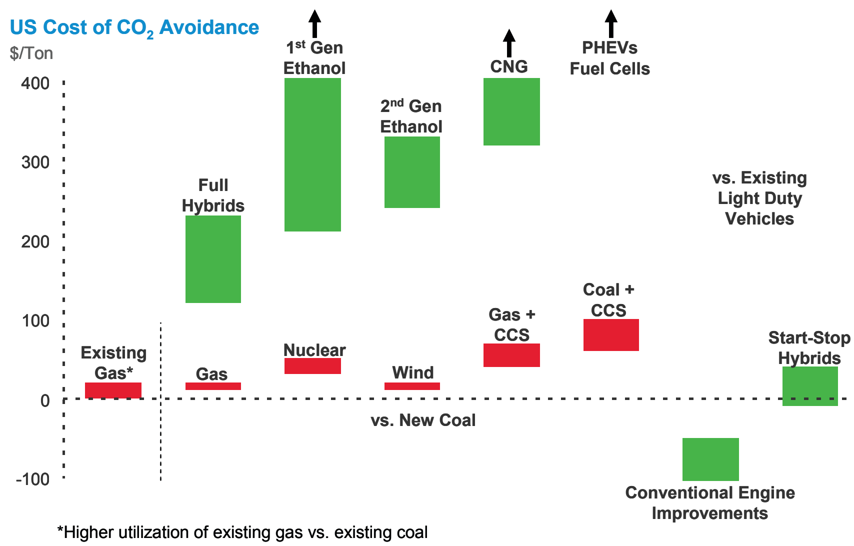
David then discussed the CO_2 emissions per kilometer, projected to 2035, for several advanced vehicles (EV, PHEV and Hybrid vehicles) and compared those values to the current and future average emissions for internal combustion engine vehicles (ICE) in the US and Europe (Figure 36). David pointed out that hybrid vehicles, such as start-stop hybrids are projected to be roughly as GHG-efficient as EVs and PHEVs on a well-to-wheels basis (with either natural gas or coal-fired power plants). He also discussed the difference in fuel economy in different regions – the average fuel economy in Europe is currently 40 per cent higher than that in the US. Regulated efficiency targets are projected to further increase fuel efficiency in both the US and Europe. In David's view, the 10 per cent CI reduction targets for the California LCFS and the RLCFRR in BC are low in comparison to the potential GHG reduction from increased vehicular efficiency.

FIGURE 36. LCA FOR FUEL/VEHICLE OPTIONS



David also presented a compilation of data from various studies that show the cost of CO_2 emissions abatement strategies that rely on specific vehicle fuels or technologies (relative to the building of new coal-fired power stations). Conventional engine improvements and mild hybridization emerged as the most cost-effective technology options, whereas the fuel and vehicle options promoted under LCFS were estimated to be among the most expensive (Figure 37).

FIGURE 37. CO_2 ABATMENT ECONOMICS FOR VARIOUS VEHICLE/FUEL TECHNOLOGIES RELATIVE TO THE IMPACT OF BUILDING A COAL-FIRED POWER PLANT



David concluded that LCFS is a complex and cost-ineffective policy to reduce GHG emissions. On a cost per unit of GHG emissions reduced, transportation fuel-related cost reductions under an LCFS regime substantially exceed the cost of other GHG emissions reduction strategies. David argued that if policy goals are to promote biofuels or to electrify the vehicle fleet, then direct and transparent regulations are better ways to meet these goals. David further explained that if the policy goal is GHG emissions reduction, then the most efficient and cost-effective approach is to employ a broad-based, revenue-neutral carbon tax. Moreover, regionally fragmented LCFS regulations increase the risk of restricting transportation fuel supplies (i.e., rationing), and of creating competitive disadvantages compared to neighbouring jurisdictions. David cautioned that the limited supply of low-carbon biofuels to meet LCFS mandates, may result in higher fuel manufacturing costs while failing to reduce GHG emissions due to fuel shuffling – especially in the case of state-level or regional LCFS implementation, as opposed to a market-wide policy. Lastly, a LCFS that debits certain crudes (e.g., Canadian oil sands) with a CI penalty may reduce US energy security while, quite perversely, *increasing* CO_2 emissions globally due to more transport of those crudes.

Chapter 4: "Low-Carbon" Vehicle Fuel System and Powertrain Technologies – An Examination of the Options for Reducing GHG Emissions over the Fuel Supply and Vehicle Operations Lifecycle

POLLUTION PROBE
CLEAN AIR. CLEAN WATER.

Chapter 4: "Low-Carbon" Vehicle Fuel System and Powertrain Technologies – An Examination of the Options for Reducing GHG Emissions over the Fuel Supply and Vehicle Operations Lifecycle

As previously discussed in chapter three, LCFS are intended to motivate reductions in the GHG emissions associated with the production, distribution and use of transportation energy commodities. This reduction, however, is not to be achieved by reducing demand for energy, as is the case with energy efficiency regulations or demand management programs. Rather, the contribution of LCFS to GHG emissions reductions is achieved by reducing the average carbon-equivalent emissions intensity (CI) of the pool of energy supplied to market to power transportation systems over the entire lifecycle of those energy commodities, from well-to-wheel.

It is not just the energy commodity (be it gasoline, diesel or electricity) that is implicated in the LCFS, but how effectively that energy commodity (or fuel) is used to power vehicles (such as personal cars, public transit systems or freight carriers). This is why the energy effectiveness ratio (EER), which is a function of vehicle powertrain efficiency,[8] plays an important role in determining whether a given fuel constitutes a low-carbon option and part of a pathway to regulatory compliance. It also explains why the production of low-carbon fuels requires that vehicles capable of using the fuels are present in the market.

To better understand the nature of the implications of LCFS for conventional and alternative fuel supply systems and the supporting infrastructure, as well as the current and future state of vehicle powertrain technologies, Pollution Probe invited six experts to the workshop to speak on the issues and to identify, in their opinion, the likely (and unlikely) options in the context of LCFS compliance. The speakers' presentations and the Q&As that followed constituted Session 1-3 B of the workshop agenda (see Appendix E1 - Appendix E6).

The first three speakers, Ken Mitchell, John German and Dr. Sam Shaw, focused on existing and established technology platforms: the current petrochemical fuel system that supplies the majority of BC's demand for transportation energy (e.g., gasoline and diesel), the state of conventional vehicle powertrain development, and the status of natural gas-powered vehicle technology and infrastructure. The three speakers that followed (Alec Tsang, Christina Ianniciello and Juergen Puetter) focused on the future potential of emerging fuel and vehicle powertrain options, including electrically-powered vehicles (EVs), strategies for advancing market transformation to support advanced technology, such as the hydrogen fuel cell, and the synthesis of conventional fuels from non-conventional sources, such as waste products from industrial processes (an option that is not well represented among those currently identified and characterized under LCFS).

8 Vehicle powertrain efficiency: A vehicle's powertrain consists of the engine, the transmission and the components that distribute power to the wheels. Internal combustion engines convert the chemical potential energy in the fuel into kinetic energy (i.e., mechanical motion), which is distributed through the transmission and differential gearing to the wheels. The more efficiently the engine can convert the fuel into mechanical power, and the more efficiently that power can be delivered to the wheels, the greater the powertrain's overall efficiency. Due to special properties of combustion, some fuels can be more efficiently converted in an engine than other fuels. This is reflected in the EER and thus it is a factor determined by the inherent efficiency of the powertrain.

4.1 Petrochemical Fuels for Transportation in BC

Ken Mitchell presented on petroleum refining processes as they relate to transportation fuels in BC, as well as product distribution and relevant standards for fuel quality. This established a common understanding of the current, dominant system for supplying transportation energy to end-users in the province. Equipped with this understanding, the workshop participants could better consider the implications of changes to the system resulting from the implementation of LCFS.

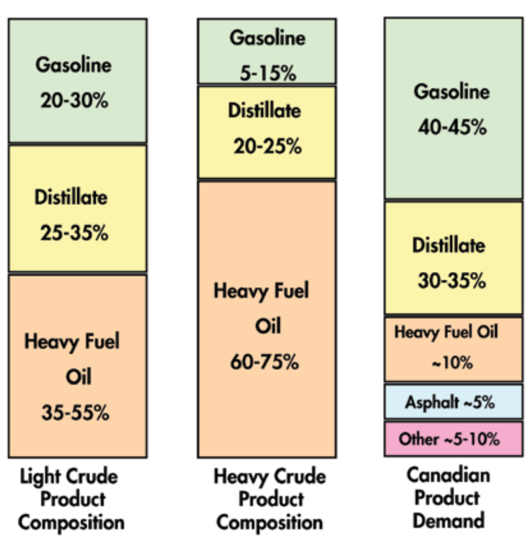
Beginning with the fundamentals, Ken noted that the arrangement of hydrocarbon molecules, as they are found in their natural, crude petroleum (i.e., oil) form, do not satisfy consumer needs for powering transportation and other services. The refining process adjusts the molecules, reshaping them and removing contaminants to ensure that they meet requirements for end-use and environmental performance.

Refining processes include distillation, in which different molecular components are drawn off of the crude feedstock through evaporation – molecular weights separate at different temperatures – and subsequent condensation into liquids that have similar boiling ranges. These components are typically referred to as heavy fuel oil, distillate fuels, gasoline, etc.

These separated components can be further refined through more advanced chemical conversion processes such as catalytic cracking, hydro-cracking, coking, reforming, alkylation, polymerization and isomerisation, hydro-treating and other chemical treating processes. In turn, these processes increase the potential value of the crude oil by producing a wider range of products that are finely tuned to perform well in specific end-uses that are in high demand or are needed to meet certain environmental criteria. Blending of various streams of components is then used to achieve required end-product characteristics.

Ken noted that the composition of the crude supplied to Canadian refineries is not perfectly matched to the demand of the Canadian market. For example, of the lighter crudes supplied to refineries in Canada, about 20-30 per cent of the component output is gasoline; for heavier crudes, the gasoline output ranges from 5-15 per cent (Figure 38), whereas end-user demand for gasoline constitutes 40-45 per cent of overall demand for refined petroleum products. Therefore, refineries must upgrade the crude to provide the quantities of gasoline needed by the market. Finished products are also imported in some regions of the country to maintain supply to the market.

FIGURE 38. PRODUCTION OF REFINED PRODUCTS COMPARED TO MARKET DEMAND



Bio notes: Ken Mitchell, Fuels Product Quality Excellence Lead, Shell Canada

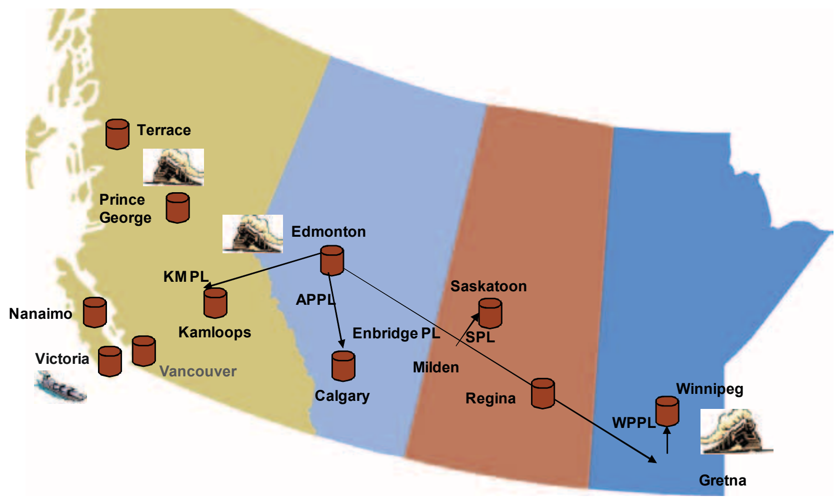
Ken Mitchell, currently a Fuels Product Quality Excellence Lead at Shell Canada, has over 30 years of technical experience working with fuels and automotive lubricant formulations.

Ken is the author (or co-author) of a number of published papers on technical issues with fuels including diesel lubricity, diesel cold operability and diesel emissions, gasoline emissions, HCCI performance and emissions. He also chairs both the Canadian General Standards Board (CGSB) Petroleum Coordinating and Middle Distillates Committees and the Gasoline Committee Working Group.

Ken has a Bachelor's and Master's degrees in Mechanical Engineering from the University of Waterloo, Ontario. He is a registered Professional Engineer in the province of Alberta and member of Society of Automotive Engineers (SAE), American Society for Testing and Materials (ASTM) and American Society of Mechanical Engineers (ASME).

Petroleum products leave the refinery and are distributed to markets by pipelines, by ship or barge to primary terminals, or by rail to primary or secondary terminals, or directly to a customer, typically by truck (Figure 39). From primary terminals, products are shipped by barge, rail or truck to secondary terminals or final points of sale. From secondary terminals, trucks carry products from secondary terminals to final points of sale. Ken provided a map showing the primary sources and routes by which petroleum products are distributed throughout Western Canada.

FIGURE 39. PETROLEUM PRODUCT DISTRIBUTION IN WESTERN CANADA



The BC market for fuels draws on a set of technologically sophisticated and complex refineries in the province, as well as in Alberta and Washington State. The four main sources of BC transportation fuels are the Husky refinery in Prince George, the Chevron refinery in Vancouver and refineries in Edmonton delivered through the Kinder-Morgan pipeline and marine imports into Vancouver from Washington State. These refineries also supply other markets in Canada and the US Northwest. In these markets, the products must comply with fuel quality regulations and standards designed to facilitate:

- Compatibility with the distribution and storage systems, thus avoiding corrosive interactions with the constituent metals and elastomer materials;
- Compatibility with vehicle fuel systems, including interactions with materials but also with evaporative emissions control systems;
- Engine durability, including lubricant interactions;
- Proper functioning of on-board diagnostic systems, including interactions with oxygen sensors in the exhaust;
- Proper functioning of exhaust after-treatment devices, including catalyst materials, absorbers and traps (too high a sulphur content in the fuel, for example, can temporarily impede the functioning of catalytic converters to reduce harmful hydrocarbons and oxides of nitrogen in engine exhaust); and
- Operability of vehicles in cold weather and hot fuel handling.

In Canada, national fuel standards are developed by the Canadian General Standards Board (CGSB) under a mandate from the Standards Council of Canada, which sets forth more than 50 criteria that govern the consensus-building process. The current portfolio of National Standards of Canada for Fuels is shown in Ken Mitchell's presentation deck in Appendix C1. These standards already provide for some use of low-carbon fuels, as follows:

- Ethanol can be used up to 10 per cent by volume in vehicles currently on-road and in-service, and "flex-fuel" vehicles can use up to 85 per cent ethanol;
- Biodiesel can be used at up to 5 per cent in the existing fleet and in Type 2 Heating Oil,
- Biodiesel can be used at up to 20 per cent by knowledgeable users, such as trained fleet managers;
- "Renewable diesel", such as hydrogenation-derived renewable diesel (HDRD) and hydrotreated vegetable oil (HVO) can serve as "drop-in" biofuels, which are chemically indistinguishable from the host fuel; and
- Propane can be used by vehicles appropriately designed (no CGSB standard is currently in place for compressed or liquefied natural gas, a standard for CNG was developed in the 1980s but abandoned due to changes in the marketplace).

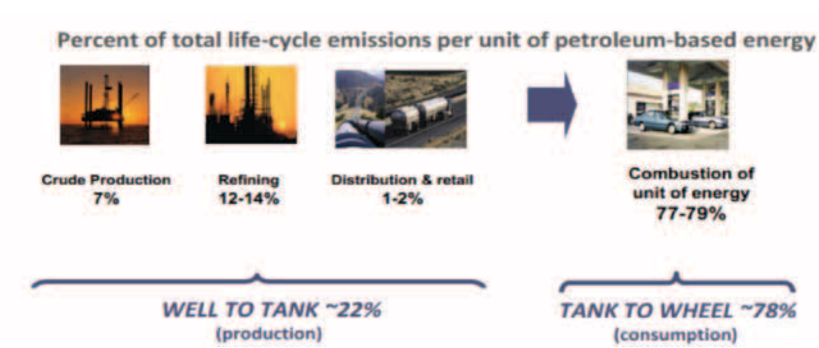
In Ken's view, the RLCFRR eventually pushes the composition of transportation fuels beyond currently available consensus standards. The higher levels of biofuel use accommodated by CGSB standards already have an impact on in-service engine durability, and excessive levels of alkali metals from biodiesel manufacture can inhibit proper functioning of catalysts in exhaust after-treatment systems. Furthermore, the average age of vehicles in-service in BC is approximately seven to eight years, and these average vehicles are not expected to retire from service for at least another five to seven years. Ken believes that the impacts of the RLCFRR on fuel compositions should consider these constraints.

Ken also noted that the implementation of RLCFRR should also consider impacts on the fuel distribution system and related infrastructure. Biofuels, for example, are transported by rail and truck to terminals where they are blended with petroleum products. Efficient terminal operation normally consists of products inbound by pipeline and outbound by rail and truck. By bringing feedstock into the terminal by rail and truck, operational efficiency is significantly lessened.

Operational efficiency is important as it impacts the GHG emissions associated with the fuel production and distribution elements of the lifecycle governed under the RLCFRR. Ken presented an image that separates the entire well to wheel lifecycle into its and tank-to-wheel emissions components (Figure 40).

Note: The RLCFRR mandates reduction of total Well-to-Wheel emissions CI by 10 per cent

FIGURE 40. SHARE OF TOTAL LIFECYCLE EMISSIONS PER UNIT OF PETROLEUM BASED ENERGY



Siding with the views expressed by earlier presenters, Ken noted that the majority of GHG emissions are produced in the tank-to-wheel or “downstream” portion of the lifecycle, whereas the RLCFRR obligates parties in the well-to-tank portion of the lifecycle. He argued that this policy approach is technology-forcing on the demand side of the system, using supply as the control variable. To complicate matters further, Ken noted that refineries are subject to site-specific GHG emissions regulations at a federal level, and that carbon pricing already exists in BC (i.e., a $10/tonne carbon tax) and Alberta (i.e., the Specified Gas Emitters Regulation, under which emissions in excess of prescribed limits are priced at $15/tonne).

In summary, Ken explained that effective regulations must provide clarity, certainty and alignment among trading jurisdictions and time for technology and infrastructure to adjust. The RLCFRR in BC, in his opinion, fails to meet these criteria.

Ken also advised that regulators consider the importance of the consumer, whose preferences ultimately drive demand for transportation fuels and technology. This bridged into the next presentation on the current state of conventional vehicle technology and the factors influencing its future development.

Bio notes: John German, Senior Fellow and Program Director, International Council for Clean Transportation

John German is a Senior Fellow and Program Director at the International Council for Clean Transportation (the ICCT), with primary responsibility for technology innovation and US policy development.

John has been involved with advanced technology and efficiency since joining Chrysler in 1976, where he spent 8 years in Powertrain Engineering working on fuel economy issues. He then spent 13 years doing research and writing regulations for US EPA Office of Mobile Sources’ laboratory in Ann Arbor, Michigan, followed by 11 years as Manager of Environmental and Energy Analyses for American Honda Motor Company. John is the author of a variety of technical papers and a book on hybrid gasoline-electric vehicles published by the Society of Automotive Engineers (SAE). He was the first recipient of the Barry D. McNutt award, presented annually by SAE for Excellence in Automotive Policy Analysis.

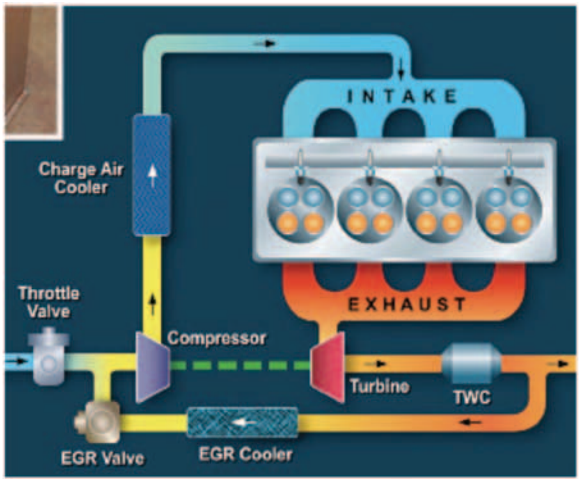
John has a bachelor’s degree in Physics from the University of Michigan.

4.2 Vehicle Technology: Near-Term Developments and Factors Influencing Long-Term Adoption of Fuel Alternatives

John German presented on the expected developments in conventional vehicle powertrain technology and the factors that would likely influence consumers’ interest in low-carbon alternatives. This provided the audience with a primer on the state of technology and its potential performance compared to the alternatives expected under LCFS. John began by profiling some recent innovations in gasoline engine technology that could reduce heat and pumping losses sufficient to approximate diesel engine efficiency. In other words, technologies such as variable compression ratio control, homogenous charge compression ignition, digital valve actuation and cooled exhaust gas recirculation (EGR) used in combination with other fuel-saving enhancements, promise to produce equivalent power while using 30 per cent less gasoline and producing 30 per cent fewer GHG emissions than current gasoline engines.

Another technology that is close to market-readiness is turbo-boosted EGR engines (Figure 41). This design relies on established technologies (EGR and turbochargers) not only to boost the intake air, but also use the turbocharger to boost the available exhaust gases for recycling into the intake air. Exhaust gases are essentially inert and can be used to dilute the combustible fuel and air mixture. This reduces pumping and heat losses, similar to diluting the fuel-air mixture entering the combustion chambers of the engine with lean air/fuel mixtures. Furthermore, this design effectively cools the fuel-air mixture, allowing for greater compression without spontaneous detonation.

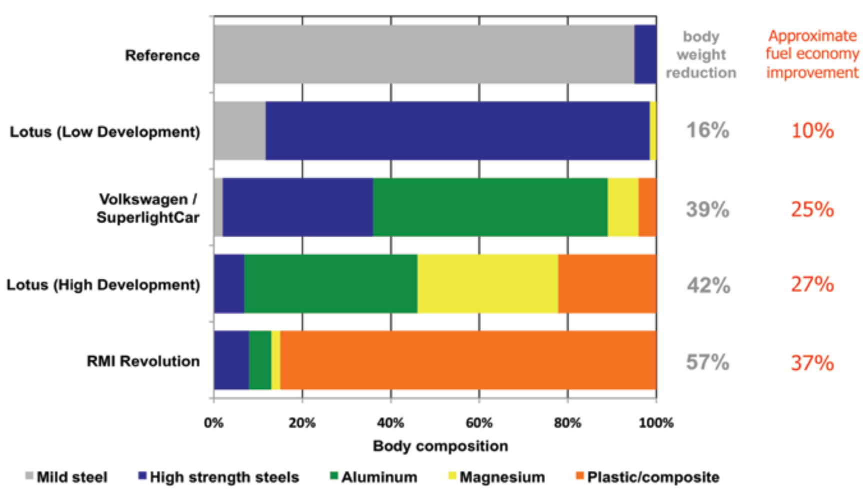
FIGURE 41. TURBO-BOOSTED EGR ENGINE



By improving engine efficiency, the above-noted technology innovations could contribute to substantial reductions in GHG emissions by allowing smaller engines to perform the work of larger engines that would otherwise require more fuel. Advancements in ignition systems will be needed for some of these technologies to be successfully commercialized.

The use of lightweight materials, particularly in light-duty vehicle construction, can also contribute to substantial fuel savings and GHG emissions reductions, by reducing the inertial loads that engines must overcome to accelerate vehicles (a major energy demand in urban stop-and-go driving conditions). Through a progression from mild steel to high-strength steel, aluminum, plastic and composite materials, mass reductions can be achieved that yield similar per cent reductions in fuel use while maintaining vehicle size. (Figure 42)

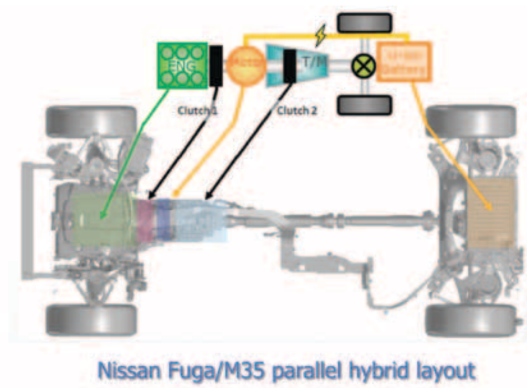
FIGURE 42. MATERIAL COMPOSITION OF LIGHTWEIGHT VEHICLE BODY AND EXPECTED FUEL SAVINGS



Developments to further reduce rolling resistance and aerodynamic resistance are also underway, which can further reduce GHG emissions from vehicles.

John noted that all of the above enhancements exhibit strong synergies with advancements in hybrid-electric technology. The electric motor eases the load on the engine, enabling additional engine efficiency enhancements. Hybrid technology relies on high voltage electronic control systems, which enable further efficiency improvements in the transmission and in mass reduction, since fewer mechanical loads and linkages are required to power components (Figure 43).

FIGURE 43. HYBRID-ELECTRIC POWERTRAIN ASSEMBLY

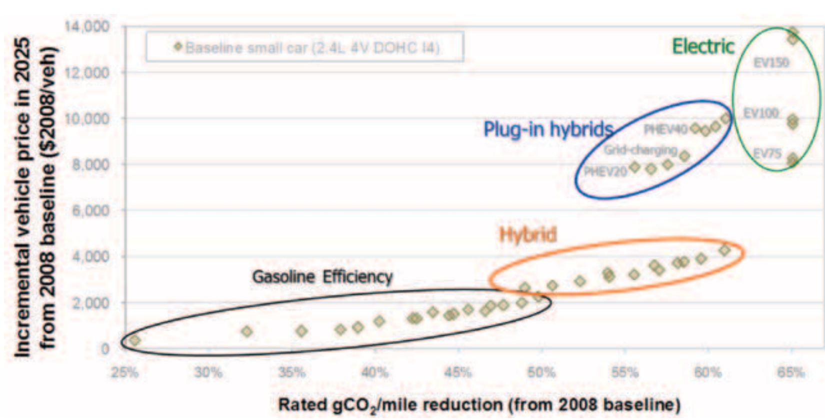


John also pointed out that the costs of hybrid technologies are dropping. Innovations, such as parallel two-clutch systems (known as “P2 hybrids”), enable either the engine or the motor to deliver power to the wheels. This level of flexibility already exists in more complex systems, such as Toyota’s Synergy Drive (known as “powersplit” systems), but the two large motors required in the powersplit system add cost. By contrast, the P2 hybrids could deliver up to 90 per cent of the benefits, but at a one-third cost reduction. P2 systems are appearing in models from Nissan, Volkswagen, Hyundai, BMW and Mercedes-Benz.

John then reflected on the development of high-power lithium ion batteries in the 2015 timeframe, which might enable the use of smaller, lighter and less expensive batteries.

Cost-benefit analyses of various technology packages and vehicle class scenarios were evaluated, based upon the regulatory impact analysis of the recently proposed joint rulemaking of the US Environmental Protection Agency (EPA) and the National Highway Traffic and Safety Administration (NHTSA, at the Department of Transportation), in terms of the potential to reduce GHG emissions and improve fuel economy of new light-duty vehicles of model years 2017-2025. John presented some of the findings in a chart (Figure 44).

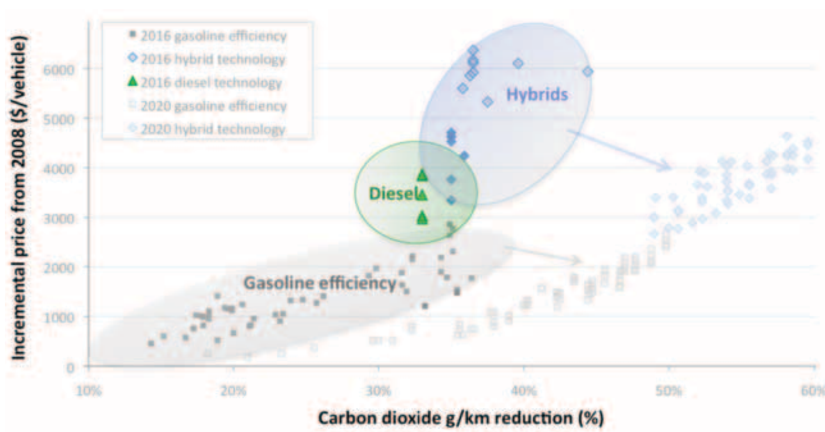
FIGURE 44. COST-BENEFIT ANALYSIS OF IMPROVED VEHICLE TECHNOLOGIES



Note: Incremental improvements in fuel efficiency (ordinate) reflect an incremental cost to the consumer due to the new technology packages. The approximated per cent reduction in CO_2 emissions is also shown (abscissa). The package descriptions (e.g., "Gasoline efficiency", "Hybrid") represent approximate terminology for purposes of illustration. Emissions avoided as a result of using grid electricity to charge EVs is based on US EPA assumptions and accounting methods for US electric grid (558 gCO_2e/kWh) for electric and plug-in hybrids.

John pointed out that, over time, the availability of technology increases, while the associated costs decrease. He presented a chart that illustrated the costs for certain technology packages in the 2017-2025 rulemaking (of the US EPA) compared to those in the previous joint rulemaking of the US EPA and NHTSA for 2012-2016 model years (Figure 45). This chart indicates that the costs of improving powertrain efficiency, especially for advanced diesel and hybrid powertrain technologies, are dropping rapidly.

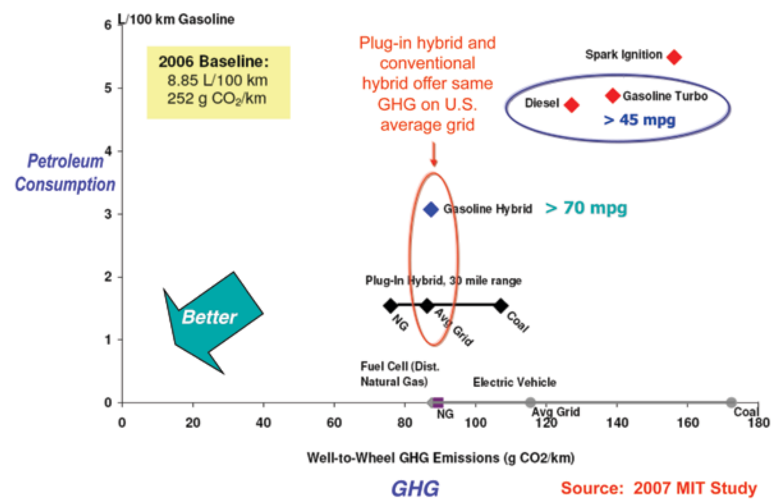
FIGURE 45. INCREMENTAL COST OF REDUCING CO_2 EMISSIONS WITH TECHNOLOGY



The technology assessments conducted by the EPA and NHTSA demonstrate a pathway to a 4 per cent *annual* rate of reduction in CO_2 emissions from 2017-2025, which relies mainly on incremental efficiency improvements to the gasoline engine combined with vehicle "lightweighting" strategies. This pathway is associated with estimated incremental costs to new vehicles of about $1,400, compared to lifetime fuel savings of $7,600, representing a payback of 1.9 years. Following this pathway, in 2025 the average new vehicle sold in the US would be rated at approximately 50 miles per gallon.

John compared these staggering rates of improvement to the performance of emerging plug-in hybrid and fully electric-powered vehicle options. By plotting hybrid, plug-in hybrid and electric vehicles according to their respective capacities to reduce petroleum consumption *and* GHG emissions in the US, John illustrated that the reductions in petroleum use can be greater than the reductions in emissions, because of the carbon intensity of the electricity supplied to the plug-in models in the US (in other words, the level of petroleum displaced by electricity does not necessarily reduce emissions by the same degree). He also noted that although the costs of the plug-in vehicles are much higher than for standard hybrids, the emissions reduction potentials are similar (Figure 46). While applicable to the US nationally, the implications would be different in BC, where the grid is principally powered by low-emissions energy sources. Nevertheless, John reminded that the dominant market for vehicle technology in North America is the US.

FIGURE 46. COMPARISON BETWEEN DIFFERENT VEHICLE OPTIONS ON THEIR CAPACITY TO REDUCE GHG EMISSIONS AND PETROLEUM CONSUMPTION



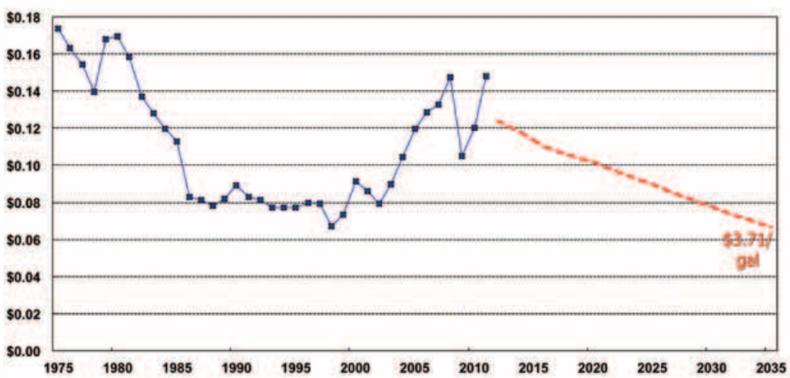
After presenting on the technological options for reducing vehicle GHG emissions, John turned his focus to the consumer. How does the consumer (the transportation energy end-user) perceive the benefits and how does this translate into demand for fuel-saving vehicle technologies? Unfortunately, the findings of many studies and research indicate that consumers are highly “loss-averse”, meaning that they tend to heavily discount the value of future, uncertain fuel savings relative to the cost of an investment in fuel-saving technology today.

There are many reasons for this discounting to take place, including the fact that few drivers compile information on their driving patterns and fuel use sufficient to conduct a quantitative assessment of the value (to them) of fuel efficiency. In 2004, a study of 60 households in California showed that only four tracked their annual fuel costs. This implies that few vehicle purchase decisions are made based on ‘rational’ considerations of fuel efficiency. Even if they were, there are many reasons why consumers would discount the value of future fuel efficiency savings. These include uncertainty about how long the car will be owned and used, how much driving will be done and what the cost of gasoline will be during the period of ownership (not to mention that the perception that better fuel efficiency requires a trade-off against other valued vehicle attributes). In John’s view, all of these factors cause the market to produce less fuel economy than is economically efficient.

Bridging from this point, John asserted that consumer loss-aversion constitutes the economic case for regulating fuel efficiency in new vehicles. Viewed this way, fuel efficiency regulations mobilize the deployment of technologies in a manner that reduces fuel consumption and GHG emissions at a level that nets a positive economic impact, at least socially, if not individually. John referred to alternative policy options to address consumer loss-aversion, including fuel taxes, which increase the cost of driving, and “feebates”, which pay manufacturers and consumers up front for the value of fuel savings (in the form of *rebates* for efficient vehicles, which are funded through *fees* applied to manufactures and to consumers, who desire vehicle attributes other than fuel efficiency).

There is, however, an important implication of mandated improvements in fuel efficiency that works against the case for more expensive fuel alternatives, such as those proposed as partial compliance options under LCFS. That is, as efficiency improves, the cost of driving goes down (Figure 47). After more than two decades of relatively stagnant levels of fleet-average fuel efficiency levels in new passenger cars and light trucks sold in North America (beginning in the mid-1980s), new regulations are expected to steadily increase fuel economy levels each year for the next 20 to 25 years. This will reduce the effective cost of driving a mile in a new car, as the chart below illustrates (Figure 47).

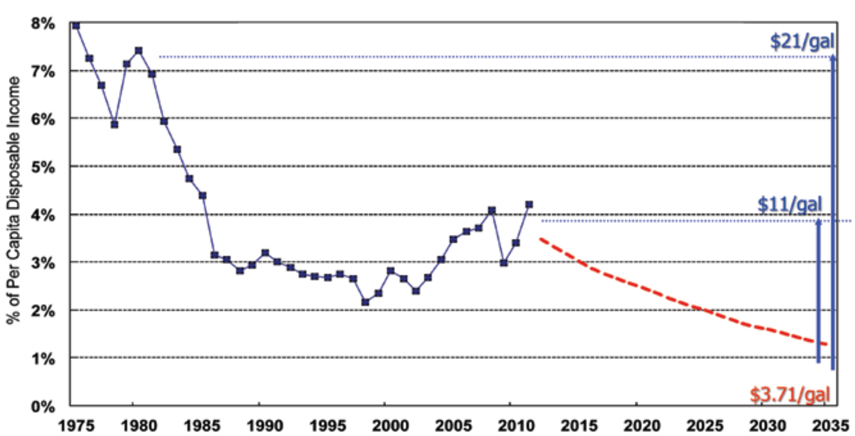
FIGURE 47. EFFECTIVE COST OF GASOLINE PER MILE DRIVEN



Presented as a share of disposable income, John inferred from the chart what the future price of gasoline would need to be to make the cost driving a mile (in a future fuel efficient vehicle) the same as the cost of driving today's less fuel efficient vehicles. He also compared this to the cost of driving in the early 1980s. Startlingly, the prices of fuel 20-25 years from now would need to approach three times the current level to keep the proportion of disposable income used to pay for fuel at current levels. That would still be less than half the proportion of disposable income paid for fuel in the early 1980s (Figure 48). The point is that despite rising fuel prices, increasing fuel efficiency levels are expected to reduce the cost of driving new vehicles in the future.

Source: BEA, Table 2.1, Personal Income

FIGURE 48. REAL FUEL COST OF DRIVING A NEW VEHICLE AS A SHARE OF DISPOSABLE INCOME



If the cost of driving a mile is declining over time, what motivation exists for consumers to consider purchasing alternatively fuelled vehicles? At this point, John bridged to a comparative analysis of some of the alternatives, beginning with Table 3, which quantifies some of the inherent advantages of liquid petroleum fuels over well-known alternatives.

TABLE 3. ENERGY DENSITY MEASURED IN KWH PER VOLUME AND WEIGHT FOR THE DIFFERENT FUEL OPTIONS

	Energy density per volume		Energy density per weight	
	kWh/liter	**vs. gasoline**	**kWh/kg**	**vs. gasoline**
Gasoline	9.7		13.2	
Diesel Fuel	10.7	110%	12.7	96%
Ethanol	6.4	66%	7.9	60%
Hydrogen at 10,000 psi	1.3	13%	39	295%
Liquid Hydrogen	2.6	27%	39	295%
NiMH battery	0.1-0.3	2.1%	0.1	0.8%
Lithium-ion battery (present time)	0.2	2.1%	0.14	1.1%
Lithium-ion battery (future time)			0.28?	2.1%

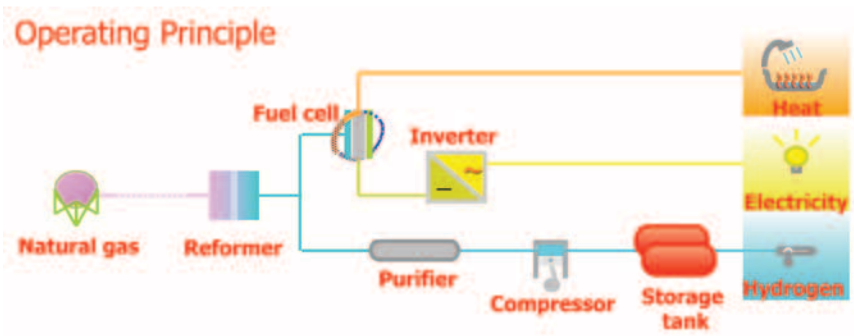
	Advantages	Needed improvements
Electricity	• Existing electricity generation • Battery charge/discharge losses lower than fuel cell losses	• Driving range and charge time – need energy storage breakthrough • Lower carbon grid • Safe place to plug in • Public charging stations
Hydrogen	• Fast refill, adequate range • Remote generation (wind, geothermal, waves, solar) • Cogeneration – heat and electricity for home, fuel for car	• Better ways to create and distribute hydrogen • New infrastructure for dispensing • Long term goal of low/zero emissions H2

John described both the electricity to power EVs and the hydrogen to power vehicles equipped with fuel cell power plants as being energy carriers – not energy sources. This characteristic translates to a range of barriers to their widespread adoption, mainly relating to technology readiness and available infrastructure.

Added to this, John says, plug-in hybrids and pure EVs face steep challenges regarding consumer adoption. The uncertainties of ownership and operation will continue to be a challenge in the early stages of the EV market. As for hydrogen fuel cell-powered vehicles, the barriers are somewhat different and are all on the infrastructure side. The US Department of Energy (DOE) estimated that the cost of transitioning to infrastructure and technology supportive of fuel cell vehicle use to be on the order of \$25-\$40 billion.

To achieve scales of economy sufficient for a breakthrough, integration of transportation and home energy solutions may be part of the solution. Honda's 4th generation Home Energy Station, in development with Plug Power, reforms natural gas into hydrogen, some of which powers a stationary fuel cell that supplies home heat and power, while the balance is purified and pumped into a storage tank, to be transferred later to a vehicle powered by a fuel cell or by a hydrogen combustion engine. Integration strategies like this may be the means to unlock the value proposition of EVs and fuel cell technology (Figure 49).

FIGURE 49. HONDA’S FOURTH GENERATION HOME ENERGY STATION



According to John, compressed natural gas (CNG) may be a potential bridge to fuel cell use in transportation. Over the lifecycle, CNG offers a 20 per cent cut in emissions, and the use of home-based CNG fuelling stations can cost 50-60 per cent of gasoline. But here again, John warned of challenges. The current distribution infrastructure and technology for CNG use is limited and expensive. Vehicles must be optimized for CNG use to deliver the full potential for environmental and economic benefits. This is counter to the previous approach of converting gasoline-powered vehicles to run on CNG. John also posed a question: is the available natural gas better used to displace coal-fired power plants as part of a more holistic strategy to mitigate GHG emissions?

Finally, John focused on biofuels, opening with a statement that it is difficult to have a low-carbon fuel policy without a high volume, low-carbon fuel. The implication is that no such fuel options currently exist. This view may be qualified by what John proposes as the properties of an “ideal biofuel”:

- has a true positive impact on GHG emissions reductions and energy security, as determined by objective lifecycle analyses;
- does not harm the environment through secondary effects, such as biodiversity loss;
- does not impact the price and availability of food supplies, directly or indirectly;
- has a pathway for sustained growth in the market;
- is compatible with legacy vehicles, small engines, etc.;
- is transparent to the consumer – performance, price and availability; and
- can be transported using the existing pipeline infrastructure.

Against these criteria, John assessed ethanol and identified the barriers to its emergence as a high volume, low-carbon fuel. Since it phase-separates in the presence of water, it cannot be shipped through existing pipelines – even in blended form. Similarly, modifications to the fuel systems of new and existing vehicles are needed to enable the use of higher concentration ethanol-blended gasoline, such as E85. Finally, the energy density of ethanol-blended and other oxygenated fuels is lower than gasoline, meaning that consumers have to pay more than the price of gasoline by volume for a fuel that takes them less distance, thus returning to the pump more frequently (Table 4).

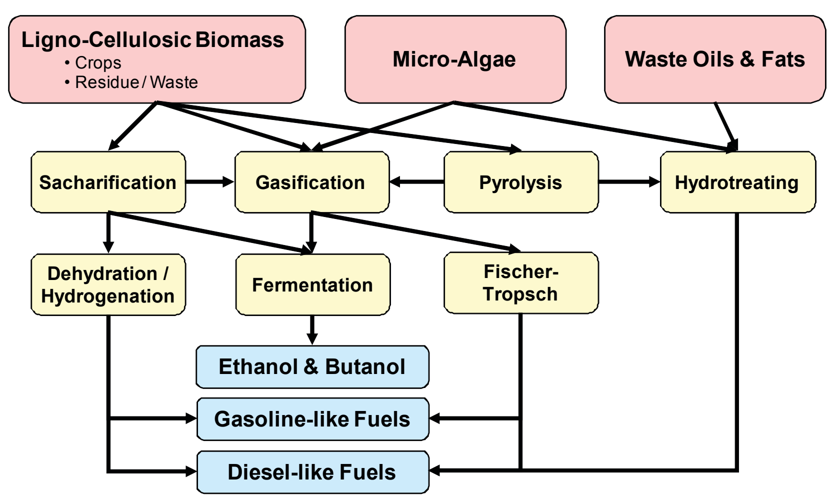
TABLE 4. PERFORMANCE OF ETHANOL COMPARED TO GASOLINE AND DIESEL

	Fuel Type					
Performance Specification	Diesel	Gasoline	E10	E85	Methanol	Butanol
Megajoules/ litre	42.5	31.6	30.6	22.7	15.6	27.0
BTU/US gallon	127,300	113.400	109,600	81,600	55,800	96,900
Research Octane Number RON		91-98	94	104-124	109	94
Motor Octane Number MON		81-89	83	88-100	89	81

As Table 4 above shows, the octane number for ethanol is substantially higher than gasoline. This means that it can operate in engines using higher compression ratios and, thus, enable higher levels of thermal efficiency. Ethanol also absorbs 2.6 times more heat than gasoline. This means that it could augment the efficiency of a gasoline engine through evaporative cooling of the gasoline-air mixture just prior to combustion, enabling a higher compression cycle. Separately injected, a small amount of E85 (say, 5 per cent of the fuel-air mixture) could enable a gasoline engine to achieve diesel efficiency levels. However, as noted earlier, turbo-boosted EGR can potentially deliver the same scale of benefits without the need for separate infrastructure and dual onboard fuel tanks.

John noted that multiple technologies and processes exist to synthesize transportation fuels from non-food biomass sources, which are fungible with conventional fuels (Ken Mitchell characterized these as “drop-in” fuels). These are better fits with John’s criteria for ideal biofuels, but they are currently scarce and expensive (Figure 50).

FIGURE 50. NON-FOOD BIOFUEL FEEDSTOCKS



Lastly, John cautioned that unless LCFS incorporates and accurately reflects the impacts of direct and indirect land-use changes associated with the cultivation of conventional biofuel feedstock, then “next generation” biofuels, such as cellulosic biofuel, will be disadvantaged in the market.

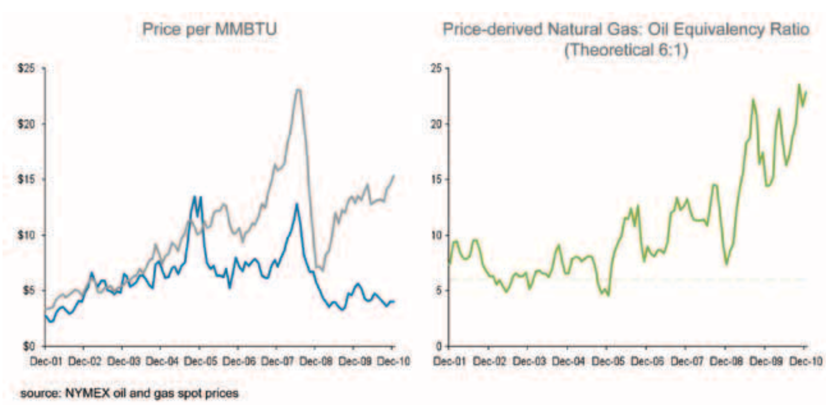
John concluded by summarizing the key points of his presentation as challenges to the successful implementation of LCFS in BC: First, the limited availability of what he characterized as ideal biofuels would not be addressed by the current structure of the regulation, and it does not constitute a strong driver of very low-carbon fuels (since it rewards the production of high volume fuels). Second, the prevailing disposition of most consumers to be risk-averse in the face of adopting new and alternative vehicle technologies is a major barrier to the uptake of low-carbon fuels and powertrain systems. John expects consumers to "wait on the sidelines" until a winning solution emerges. Finally, the projected decline in the real cost of driving would further inhibit consumer adoption of the types of fuels and technologies that are supposed to be advanced by the LCFS.

4.3 The Role of Natural Gas in Low-Carbon Transportation

Dr. Sam Shaw presented an overview of the current status of natural gas vehicle (NGV) technology and the potential for market expansion. The contribution of NGVs to achieving compliance under LCFS was explored, and the barriers and opportunities to widespread adoption in light- and heavy-duty applications was identified and characterized.

Sam began by noting the recent changes in supply and demand for natural gas in North America, wherein prices for natural gas appear to have decoupled from oil, and the projected abundance of natural gas is expected to maintain this difference in pricing (Figure 51).

FIGURE 51. NATURAL GAS PRICES IN NORTH AMERICA



Due to the increased supply potential, the opportunity to power vehicles with natural gas has become a priority business opportunity for Canadian gas suppliers. As well, many fleet managers in the US are considering turning over their capital stock with NGV alternatives as a strategy for managing operating costs and for achieving corporate environmental objectives.

In the context of heavy-duty vehicle operation, Sam presented a cost breakdown of liquefied natural gas (LNG) compared to diesel, based on diesel gallon equivalence (DGE) and assuming $6/MMBtu for gas and $100/bbl (barrel) for oil, as well as a 15 per cent internal rate of return on plant and retail operation. Whereas diesel costs are dominated by the price of crude and sales and excise taxes, LNG costs are more weighted towards liquefaction, distribution and retailing expenses, as well as feedstock (Figure 52). In absolute terms, natural gas has a price advantage of approximately one-third.

Bio notes: Dr. Sam Shaw, Vice President Natural Gas Policy Development, Encana Corporation

Dr. Sam Shaw is responsible for providing leadership and counsel to Encana's Natural Gas Economy team on Canadian environmental policy and legislation and its impact on our gas demand initiatives. He has a wide range of experience in leadership, government relations, negotiations, business development, project management, international relations and human resources. He joined Encana from the Northern Alberta Institute of Technology where he served as President & CEO since 1997.

Sam received the Distinguished Leadership Award from the Council for the Advancement and Support of Education District VIII; is a member of Industry Canada's Science, Technology and Innovation Council; is the Vice Chair of the Standards Council of Canada and served as Chair of the Advisory Committee TC232; was Board Member and Chair of the Human Resources Committee of the Canadian Commercialization Corporation; and is a member of Alberta Economic Development Authority. He is an adjunct professor for Cape Breton Shannon School of Business and teaches part-time for the JR Shaw School of Business. In January 2010 he was appointed Honorary Colonel of 408 Tactical Helicopter Squadron in Edmonton.

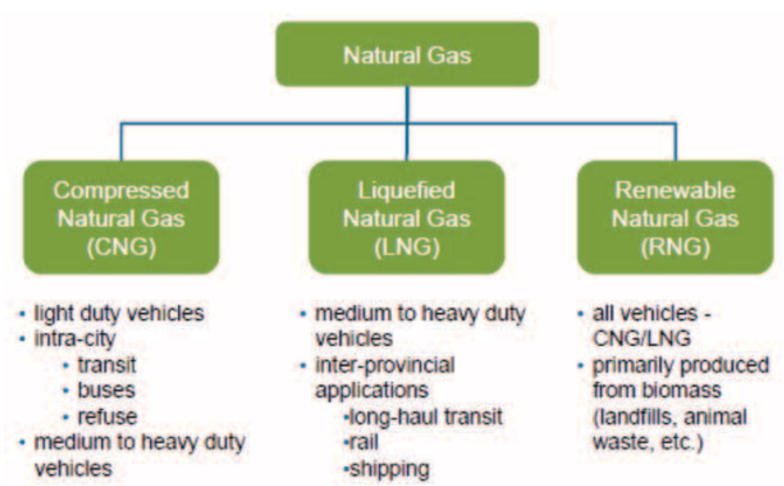
Sam holds a Bachelor of Arts from Chaminade University of Honolulu, a Master of Science from Dalhousie University and a Master of Education and a PhD from the University of Toronto. He is also a graduate of the Harvard University Institute for Educational Management and earned a Chartered Director designation from McMaster University and The Conference Board of Canada. Additionally, he is a past recipient of Alberta Venture's Businessman of the Year award and has twice been recognized as one of Alberta's 50 Most Influential People.

FIGURE 52. COST BREAKDOWN OF NATURAL GAS COMPARED TO DIESEL

The development of the global market for NGV technology is more advanced than in North America. Approximately 13.6 million NGVs are in use around the world, yet only 140,000 are in use in North America. Part of the reason for the rapid growth of NGV use in developing nations is the contribution the technology makes to clean air objectives. The cleaner-burning qualities of natural gas facilitate low-cost reductions in emissions of criteria air contaminants that contribute to photochemical smog. Jurisdictions in developing nations are challenged to match the rigour of the emissions regulations in the US and Canada, which require more expensive exhaust after-treatment technology on gasoline and diesel-powered engines.

Sam characterized the low level of NGV use in Canada as an opportunity for substantial displacement of diesel and gasoline in the overall transportation energy mix (Figure 53). He cited the versatility of the fuel, adaptable to a range of transportation services.

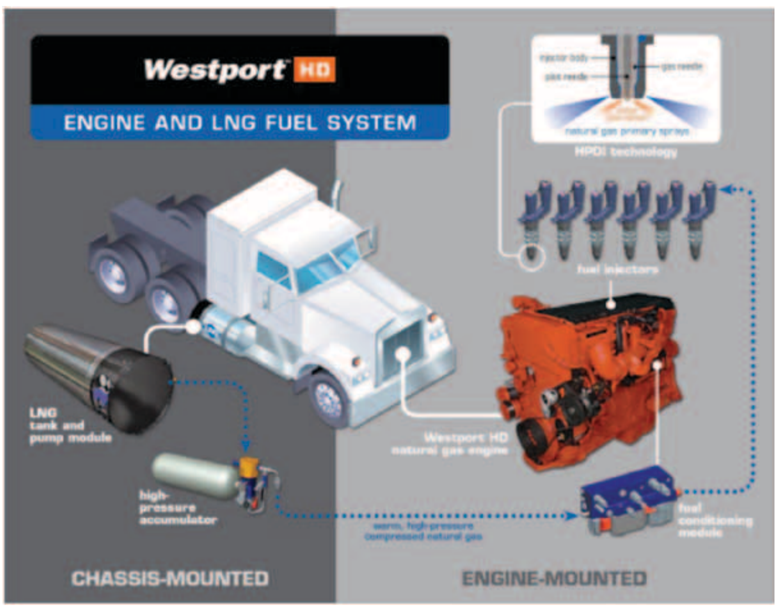
FIGURE 53. FORMS OF NATURAL GAS FOR TRANSPORTATION



In each of the cases where natural gas can be used to power vehicles, specific engine and onboard fuel storage technologies are needed, as well as supporting infrastructure for distribution. These factors have been barriers to widespread adoption of NGVs, despite the price advantage of the fuel. To build momentum and unlock the potential of NGV use, government and industry have undertaken a range of initiatives to promote and support the technology. The Government of Canada has produced a roadmap for the deployment of NGV and fuelling infrastructure. The Government of Quebec allows businesses to accelerate the write-down on the incremental capital cost of new NGVs. Gas utilities, including GazMétro in Quebec and FortisBC in the Lower, BC Mainland, are investing in NGV fuelling stations.

Canadian companies are also playing a leading role in the development of NGV technologies. For example, Westport Innovations, based in Vancouver, is a global leader in the development of natural gas injector technology for engines. In particular, Westport has pioneered systems that enable engines for heavy-duty vehicle applications to be powered by liquefied natural gas (LNG) (Figure 54). Their pumping and injector system (i.e., HPDI injectors) delivers natural gas from a cryogenic storage tank, which is filled with super-cooled natural gas, to the combustion chamber of a diesel engine. Normally, a spark plug would be needed to ignite the fuel-air mixture, but Westport’s injectors deliver a small amount of diesel that self-ignites under compression by the pistons, in turn combusting the natural gas.

FIGURE 54. NATURAL GAS INJECTOR TECHNOLOGY FOR ENGINES PIONEERED BY WESTPORT INNOVATIONS



This approach has two key benefits: (1) the natural gas is converted to power at a level of efficiency comparable to diesel engines, and (2) the onboard storage of natural gas, maintained at temperatures sufficiently low to keep it in liquid form, is volumetrically dense and therefore capable of providing energy for longer trips than is typical for NGVs. Furthermore, because the liberation of heat in the combustion of natural gas owes more to the oxidation of hydrogen (forming H_2O) than that of carbon (forming CO_2),[9] the GHG emissions “at the tailpipe” are significantly lower with LNG engines than with diesel engines for equivalent power output.

9 Natural gas (CH4) has a lower fraction of carbon atoms in its molecule compared to gasoline or diesel. As well, the heat of combustion of natural gas is higher than for gasoline or diesel. Provided the thermal efficiency of the engine cycle is equivalent, natural gas should produce more energy in combustion per unit mass than diesel.

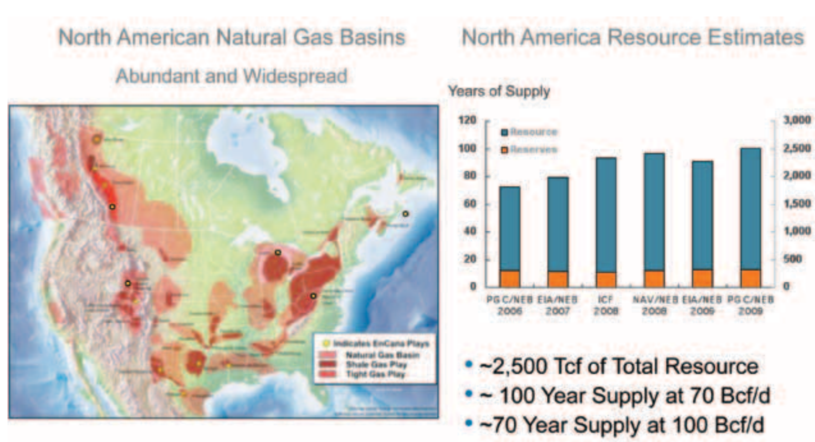
These performance characteristics have been noted by freight carriers, and orders for the technology have recently been placed by Robert Trucking, Vedder Trucking and Heckmann Water Resources. In Sam’s view, this indicates the readiness of the technology for market.

Next, Sam spoke about “LNG corridors” that Encana is promoting to make the Westport LNG vehicle technology attractive to long-haul carriers in Canada. Under Encana’s vision, heavily trafficked highways in the west and east of Canada would have strategically placed LNG fuelling stations to maximize the potential for heavy-duty LNG-powered truck use, and to reap the economic and environmental benefits of lower-cost freight transport and reduced GHG emissions. Since LNG trucks have a typical driving range of about 800-1,000 km between fill-ups, these corridors would enable shipping by LNG between Vancouver and Edmonton, and between Windsor and Quebec (Figure 55). Encana seeks government financing and permitting to realize the vision.

FIGURE 55. ENCANA’S VISION FOR LNG CORRIDORS

Echoing John German’s comments (Section 4.2) that the viability of low-carbon fuels is tied to their abundance and availability, Sam remarked on the size of the natural gas resource in North America resulting from innovations in extraction technologies and processes that have made vast deposits of shale gas economically sound for development (Figure 56).

FIGURE 56. NORTH AMERICA NATURAL GAS DEPOSIT ASSESSMENT



Sam also shared the results of several analyses of the business case for different NGV applications, ranging from heavy-duty trucking to public transit and vocational vehicles, identifying the payback periods as a function of the price differential between natural gas and oil (inclusive of taxes) and the annual distances logged. Notably, the reductions in GHG emissions resulting from the displacement of diesel and gasoline with natural gas to power vehicles of all types grows to 300,000 tonnes, based on modelling by Encana with an assumption of nearly 3,000 new NGVs in-service by 2025 (mostly in the light-duty vehicle sector).

In conclusion, Sam called for coordinated efforts on the part of original equipment manufacturers (OEMs) to bring to market a wider range of NGV models in North America, and for governments to provide incentives and programs to promote and support NGV use, as well as the creation of NGV corridors to enable long-haul trucking by LNG. As with John German, Sam identified the opportunity for natural gas home fuelling stations to be key to the NGV value proposition for personal drivers. But, he said, the per-unit cost needs to drop from the current \$5,000 to about \$1,000 to achieve mass market acceptance.

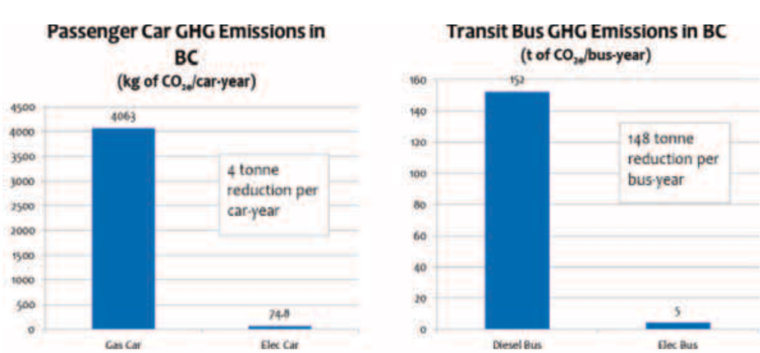
As identified earlier, natural gas is considered to be a low-carbon fuel under LCFS. But whether LCFS would be effective in addressing the barriers identified by Sam in his presentation remained unclear. Some audience members felt that NGVs could be cost-competitive with conventional technologies and fuels, but investment in infrastructure and other non-regulatory measures were the key intervention sought of government.

4.4 Grid-Powered Electric Vehicles

Alec Tsang presented on BC Hydro's approach to facilitating the introduction of EVs in BC and spoke about potential emerging fuel and powertrain options that could contribute to LCFS compliance.

Alec began by quantifying the low CI characteristics of EV powertrain technology powered by electricity drawn from the BC Hydro grid, which has an ultra-low GHG emissions profile and also exhibits one of the largest gasoline-electricity price differentials in the country. It was clear that substantive electrification of the transportation system in BC could deliver a reduction in CI far beyond what the LCFS requires by 2020 (Figure 57). However, there are many practical barriers to the rapid uptake of EV technology by consumers, including the high price of current battery technology, the relatively shorter driving range of EVs, the availability of charging infrastructure and, in some places, the preparedness of the existing grid to accommodate the demand for power to fast-charge EVs.

FIGURE 57. REDUCTIONS IN GHG EMISSIONS USING EVS POWERED BY BC HYDRO ELECTRICITY



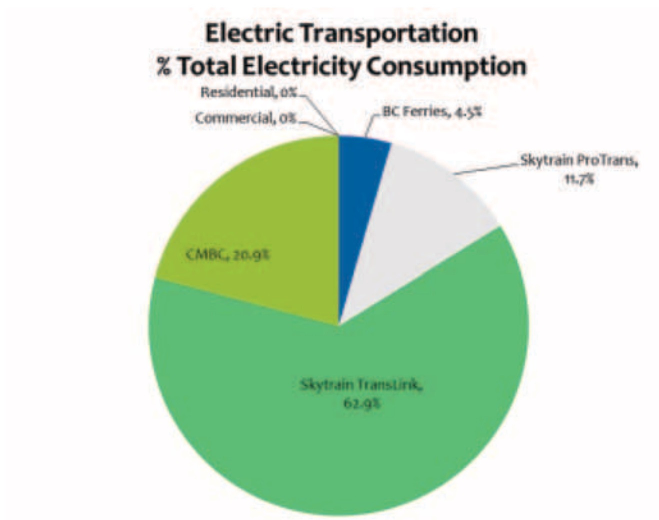
Bio notes: Alec Tsang, Senior Technology Strategist, BC Hydro

Alec is a Senior Technology Strategist with the emerging technologies group at BC Hydro. Alec is responsible for shaping BC Hydro's role in the electrification of transportation in the province of British Columbia. Alec has led Pan-Canadian initiatives for reducing barriers to EV adoption such as the development of EV infrastructure installation guidelines and the development of a public EV infrastructure deployment framework. He also leads utility EV preparations for BC Hydro: grid impacts, customer EV needs and regulatory implications.

Over the past seven years at BC Hydro, Alec has also led other emerging technology projects such as assessment and application of hydrogen and fuel cell technologies.

As the barriers and opportunities to widespread EV use are familiar to many experts in the field, Alec chose to focus a portion of his presentation on the opportunities for electrification to displace the demand for conventional fuels in the off-highway sector (Figure 58). Shore power at marine ports, ground transportation equipment at airports, truck stop auxiliary power and materials handling are all prime examples of where electrification is immediately available, is cost-effective, does not require major infrastructure investments in advance of the market and can generate significant reductions in GHG emissions upon the investment. Alec shared the business cases of two such examples: electric-powered dredging at the Port of Mobile, Alabama, and ship-to-shore electric crane loading in Savannah, Georgia.

FIGURE 58. OFF-HIGHWAY SECTORS WITH OPPORTUNITIES FOR ELECTRIFICATION TO DISPLACE CONVENTIONAL FUEL USE



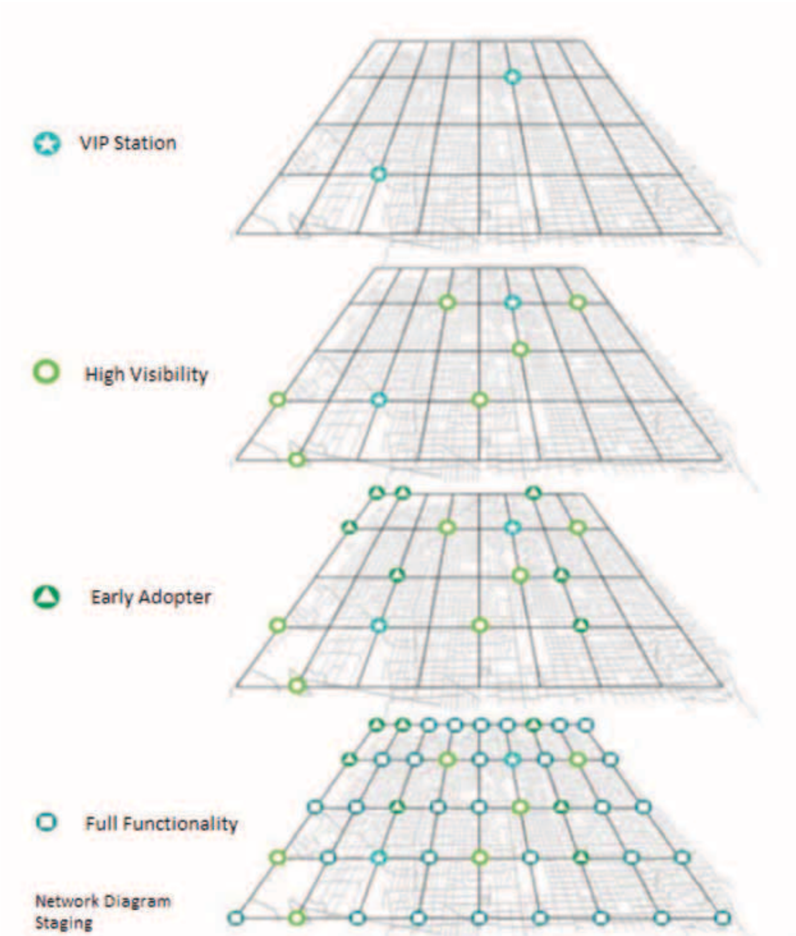
Alec the characterized the current demand for electricity to power public transit systems in BC. He noted that although the means of quantifying and crediting low-carbon transportation energy under the LCFS is unclear, BC Hydro believes that credits should remain with the utilities.

Regarding personal EV use, it is BC Hydro's belief that most charging would take place at home and that more home charging stations will be required. That said, rapid-charging options outside one's home need to be publicly available in order to boost consumer confidence in EV use. BC Hydro is currently developing a policy on EV metering, but no plans exist to establish separate charging for electricity supplied to EVs.

To inform the deployment strategy for critical EV infrastructure, Alec referred to BC Hydro's planning framework, which projects full grid functionality with EVs being achieved in a series of staged investments. At each stage, the *critical infrastructure* is that which supports the next level of market adoption. This strategy avoids investing in infrastructure that is not well-aligned with the next predicted stage of market evolution, and thus minimizes the risk of costly stranded assets – a serious concern for a publicly-regulated utility (Figure 59).

Alec concluded that public outreach and education are critical to successfully promote and sustain consumer demand for EV technology.

FIGURE 59. NETWORK DIAGRAM STAGING FOR EV INFRASTRUCTURE



4.5 Policy Framework Elements to Advance Market Transformation in Transportation Technology

Christina Ianniciello focused on policy frameworks of the BC Government that could support market transformation, characterized by the widespread adoption of advanced vehicle technologies, including NGVs, hydrogen fuel cell-powered vehicles and EVs.

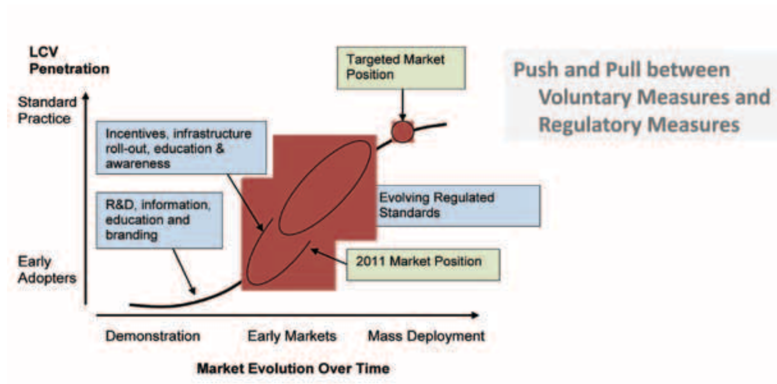
Christina presented on the status of natural gas and fuel cell technologies as they relate to transportation systems in the province. The drivers and objectives of the market transformation toward these technology platforms include reduced fuel costs and emissions, government policy and economic diversification. The barriers to transformation include higher capital costs, limited fuelling infrastructure for the alternatives, uncertainty about operational performance and maintenance costs and general unfamiliarity with the technologies among most consumers. Christina laid out the process of market transformation in a chart that illustrated the need for balance between regulatory "push" and voluntary market "pull" and for targeted interventions to sustain the momentum at critical stages of the shift (Figure 60).

Bio notes: Christina Ianniciello, Manager, Communities and Transportation, BC Ministry of Energy and Mines

Christina Ianniciello is the Manager, Communities and Transportation with the British Columbia Ministry of Energy and Mines (MEM). In her role, Christina is responsible for programs and policies related to community energy solutions and clean transportation. She works with a variety of stakeholders on policies and programs that support natural gas vehicles, plug-in electric vehicles and hydrogen fuel cell vehicles.

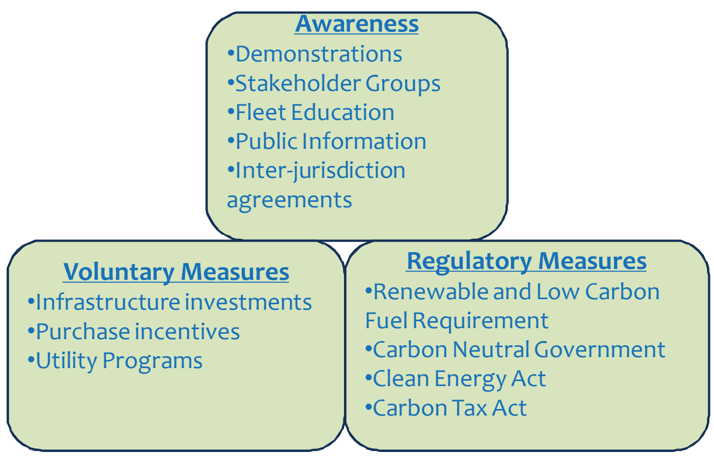
Christina holds a Bachelor of Engineering in Chemical Engineering from McGill University, and is completing her Master of Applied Science with the University of Victoria's Institute for Integrated Energy Systems. Prior to joining MEM, Christina worked as a process engineer in the mining industry.

FIGURE 60. TRANSFORMATION OF THE BC MARKET FOR ADVANCED VEHICLE TECHNOLOGIES



This bridged to the Government's organizing framework, which consists of targeted awareness-building measures, promoting voluntary initiatives and developing and enforcing regulations. It was also noted that credit trading should be facilitated by government, given that credits generated under Section 18 of the *Clean Energy Act* are supposed to remain with utilities.

FIGURE 61. BC POLICY FRAMEWORK FOR SUSTAINABLE TRANSPORTATION



Christina asserted that the near-term opportunities for NGVs, hydrogen fuel cell technology and plug-in EVs to contribute to RLCFRR compliance are limited, and she challenged the audience to propose additional measures to stimulate market transformation. An example used to spur dialogue was that an available supply of waste hydrogen from industrial processes exists in BC. This is an idea that was picked up and explored in a subsequent presentation by Juergen Puetter.

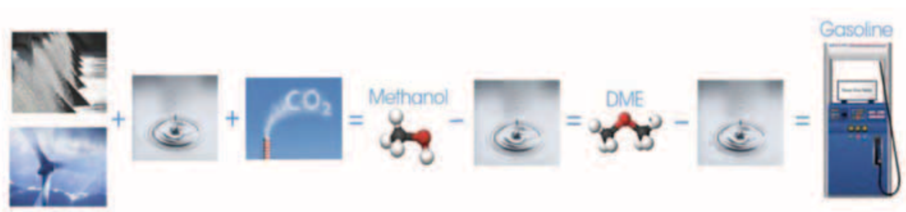
4.6 Synthesizing Industrial Waste Streams into Low-Carbon Fuels

Juergen Puetter's presentation introduced a process that produces either low-carbon methanol or gasoline by tapping into feedstocks that would otherwise be considered waste by-products of industrial gas processing. This served to highlight opportunities to build a local supply of low-carbon fuels through integrated, industrial ecology, which is a compliance pathway that is not yet well reflected in the LCFS.

Juergen began by explaining the properties of methanol – a simple alcohol that is an energy-dense liquid at room temperature – and its global production capacity, which is about 90 billion litres per year from 90 plants located around the world. As a transportation fuel, methanol can be blended with gasoline and ethanol, or it can be converted to dimethyl ether (DME) and used as a substitute for diesel. In China, 125 million litres of methanol comprise a portion of the country's transportation energy supply.

The process introduced by Juergen proposes to use methanol and its derivatives as an liquid "energy carrier" for the renewable electricity generated from BC's hydro and wind resources (Figure 62). This electricity is combined with CO_2 – a waste product of natural gas processing (i.e., cleaning and scrubbing) – which happens to be one of BC's largest point sources of GHG emissions – to form methanol. Dewatering the methanol produces DME, which can be further dewatered to produce gasoline. This synthetic gasoline, which is a product of renewable power and waste CO_2, can be "dropped" into BC's current gasoline pool, thus reducing the CI value of the pool, ready for use without requiring the development of new vehicle powertrain technology or expensive distribution and dispensing systems.

FIGURE 62. SCHEMATIC OF SYNTHETIC GASOLINE PRODUCTION PROCESS USING CO_2 WASTE AND RENEWABLE POWER



Juergen's company, Blue Fuel Energy, proposes to use 500 MW/hour of wind power potential and 2,100 tonnes per day of CO_2 that is currently emitted from a natural gas processing facility located in the BC interior (Figure 63). The power would be used for the electrolysis of water, producing hydrogen gas (H_2) and oxygen (O_2). The O_2 could be reused in the gas processing facility, while the H_2 and CO_2 would serve as essential feedstock for a new methanol production facility. The methanol could also be converted to gasoline using a commercial catalytic process developed by ExxonMobil.

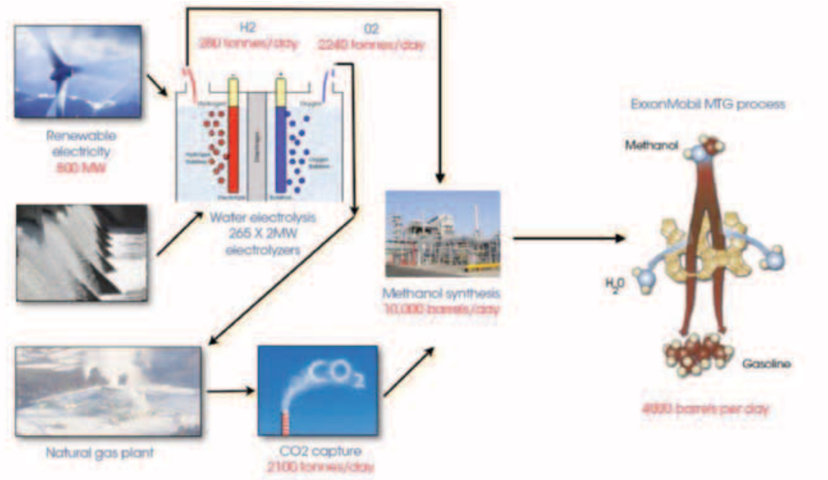
Bio notes: Juergen Puetter, President, Blue Fuel Energy Corporation

Juergen Puetter is President, CEO and Chair of Aeolis Wind Power and Blue Fuel Energy. Aeolis is a leading wind energy development organization with numerous project sites in western Canada. Blue Fuel Energy was established to produce renewable fuels from renewable energy.

Mr. Puetter has a distinguished career in converting innovative concepts into successful businesses, such as Bionaire (air purification) and Hydroxyl (water purification), among others. The Government of Canada appointed Juergen Puetter as Chair of Sustainable Development Technology Canada (SDTC) in 2008.

His academic background includes Electrical Engineering and Economics at Loyola University in Montreal.

FIGURE 63. SYNTHETIC GASOLINE PRODUCTION - PROCESS INPUTS AND OUTPUTS



The CI values for the lifecycle elements of this process were modeled by S&T[2] and are presented in Table 5. Juergen pointed out that methanol produced in this way would have one-sixth the CI of conventional gasoline in BC, although if it were further synthesized into gasoline, then the CI could be conservatively estimated at just less than half that of gasoline. This still constitutes a major reduction, and while more expensive per litre than conventional gasoline, it would be less expensive as a compliance option than many others considered under the LCFS.

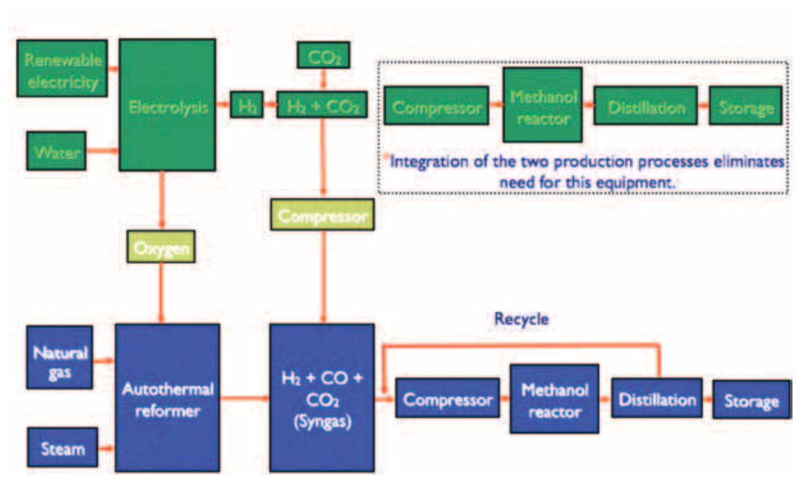
TABLE 5. CI OF METHANOL (PROCESSED TO SYNTHETIC GASOLINE) COMPARED TO CONVENTIONAL GASOLINE

Fuel		Volume	Energy Density	Carbon Intensity
		(Litres/year)	(MJ/L)	(g/MJ)
Gasoline		4,398,410,200	34.69	90.21
Canadian Wheat Ethanol		173,621,100	23.58	40.85
US Corn Ethanol (Coal)		11,574,740	23.58	73.82
US Corn Ethanol (NG)		46,298,960	23.58	61.94
Methanol from NG	Available	600,000,000	18.00	76.19
Methanol (BC avg. grid)		600,000,000	18.00	31.67
Methanol (wind power)		600,000,000	18.00	14.27

The Blue Fuel Energy process would help address a major industrial emissions challenge, and would also make use of a remote wind resource, otherwise costly to be connected to the grid with new transmission lines.

Juergen concluded by presenting a chart that shows projected emissions reductions should the methanol proposal be implemented (Figure 64). Notably, the contribution to reductions in CI of the overall BC fuel pool would be about 2.1 per cent if Blue Fuel Energy gasoline product were "dropped in".

FIGURE 64. INTEGRATION OF RENEWABLE, WASTE CO_2 AND NATURAL GAS



It was noted by some in the audience that methanol may not be a desirable fuel to blend into gasoline as it has been associated with corrosion issues. It was suggested that further processing of the methanol into gasoline might be a better alternative under LCFS in order to comply with prevailing fuel standards.

Chapter 5: Lifecycle Analysis and Regulatory Information: Understanding the Information and the Methodologies Used in LCFS

Pollution Probe
CLEAN AIR. CLEAN WATER.

Chapter 5: Lifecycle Analysis and Regulatory Information: Understanding the Information and the Methodologies Used in LCFS

Regulation frequently requires the provision of specialized information for its design and implementation. In the case of the LCFS, which is designed to reduce the average carbon intensity (CI) of transportation fuels over the entire lifecycle of the fuel, lifecycle analysis (LCA) has emerged as an essential tool in the estimation of CI for all fuel types.

Jurisdictions that have introduced LCFS-style regulations have utilized LCA as a foundational tool. However, the models (tools) and data sources employed have varied. Furthermore, the tools and information continue to evolve to meet the needs of the regulatory community and to incorporate new research. The different approaches that have been employed by California, BC and the EU have introduced challenges in the interpretation of findings and the potential influence on the trade of crude oil and refined fuel products.

Pollution Probe invited six experts to the workshop to address key aspects of the role that LCA plays in the design and implementation of LCFS, and to discuss the importance of gaps in data modeling, as well as the relationship between modeling efforts in BC to efforts in other jurisdictions.

The first three speakers, Don O'Connor, Catherine Reheis-Boyd and Anil Baral, provided an overview of LCA tools and regulatory information and their application to BC and California. Their topics covered: LCA for regulatory use, with specific reference to GHGenius, GREET and other models currently employed or under consideration; key assumptions and compliance pathways for the California LCFS and their implications for crude oil supply in California and elsewhere; and the role and state of information science for its application to LCFS.

The second group of speakers included Adam Brandt, Joule Bergerson and Chris Holly. Their presentations covered topics concerning LCA and the CIs of conventional and unconventional crude oil from perspectives on data advancements, research activities and reducing uncertainty.

5.1 Lifecycle Analysis for Regulatory Use

Don O'Connor presented an overview of LCA and its application to regulatory issues, including benefits and challenges. He also reviewed a number of LCA tools, including GHGenius, the tool utilized by the BC government for its LCFS, as well as tools used in other jurisdictions. The review established a base of understanding of LCA and LCA tools, in context of BC, California and the EU.

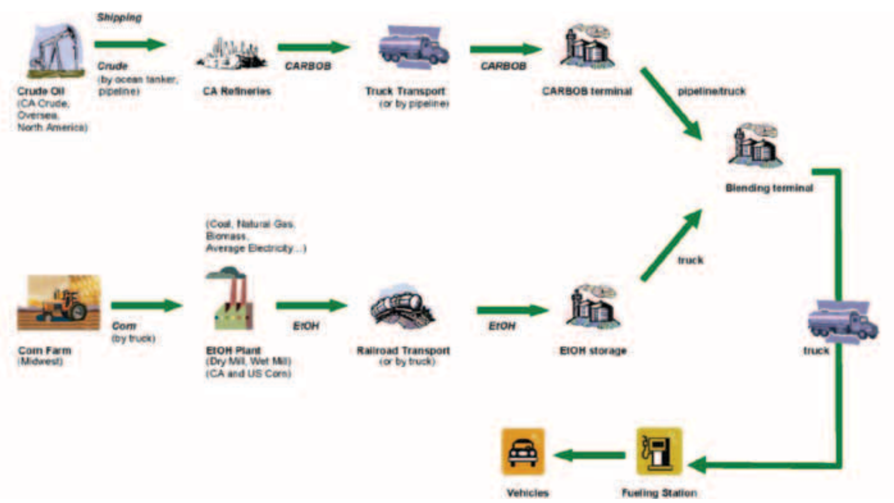
Don began by providing the US EPA definition for LCA: "a technique for assessing the potential environmental aspects associated with a product (or service) by compiling an inventory of relevant inputs and outputs, evaluating the potential environmental impacts associated with those inputs and outputs, and interpreting the results of the inventory and impact phases in relation to the objectives of the study".

Bio notes: Don O'Connor, President, (S&T) Squared Consultants Inc.

Don O'Connor has been President of (S&T) Squared Consultants Inc for the past 12 years. Don is the primary developer of the GHGenius LCA model. He is a mechanical engineer with more than thirty years of experience in alternative energy and environmental consulting, and in industry. Mr. O'Connor's background includes more than 15 years of manufacturing and marketing experience with Western Canada's largest independent fuel retailer. He has successfully developed and commercialized environmentally sound transportation energy alternatives. Mr. O'Connor has recently provided advice on fuels, transportation issues, and greenhouse gas emissions to a number of Provincial governments, several Canadian Federal Government departments, and international agencies and governments. Mr. O'Connor has also consulted for a number of companies developing new technologies for alternative fuelled vehicles and companies developing new transportation fuel processes and facilities. Mr. O'Connor has served as a director of numerous private and public sectors corporations. In addition he has served on or chaired a number of government advisory panels on transportation fuels and bioenergy, industry associations and community foundations.

Don noted additional features of LCA that make it uniquely suited to LCFS application, including the lifecycle boundary, which is cradle to grave, beginning with raw materials from excavation from the earth to ultimate disposal (Figure 65). LCA evaluates all stages of the lifecycle and treats these as interdependent. This is an important attribute in light of the multiple stages involved in the production and use of energy in the transportation sector, including the two primary phases involved in the well-to-wheel lifecycle, which are the well-to-tank and tank-to-wheel emissions components noted in Chapter 4 and illustrated in this chapter. Don discussed one of the significant attributes of LCA, which is its ability to provide a comprehensive view of all environmental impacts with the ability to accurately assess environmental trade-offs. This offers important advantages when comparing energy sources and vehicle technologies present in LCFS compliance pathways and helps decision-makers select lower environmental impact options. The LCA also offers valuable insight into where reductions are possible. In the case of the well-to-tank versus tank-to-wheel it has been recognized for some time that tank-to-wheel represents a higher portion of the GHG emissions (approximately 70-80 per cent); however, he noted that cost and environmental efficiency are both important considerations. To this end, industry can apply the LCA process as a means of identifying improved production efficiency, which can lower the CI of the fuel and related production costs.

FIGURE 65. LCA SCHEMATIC OF CONVENTIONAL AND ALTERNATIVE FUEL OPTIONS



Don cautioned that LCA is not without limitations. The approach, by design, requires in-depth treatment of multiple stages in the lifecycle, each requiring considerable research and estimation, making LCA resource intensive and potentially expensive. Quality results are often highly dependent on the availability and accuracy of data. Thus, poorer quality data can have a substantive influence on results. The quality of the data and assumptions used may be difficult to determine if the user is not transparent and forthcoming with these details – a principle that is documented within the ISO 14040 standard for Lifecycle Assessment. Unfortunately, not all LCA tools are transparent. Some can be like "black boxes", making it difficult to make sense of the model's outputs.

Next, Don explained principles beyond transparency that are incorporated into ISO 14040, including the lifecycle perspective, the environmental focus, the relative approach and functional unit, an iterative approach, comprehensiveness and the priority of the scientific approach, which can be helpful in addressing data gaps. These principles are important considerations to understand and challenge the outputs that have been used in crafting the regulation.

Don also warned that the use of LCA and LCA tools has contributed to common misconceptions. For example, some people believe there should be a single CI number for each fuel, whereas production facilities were built by different people, at different times and in different parts of the world, resulting in a wide range of lifecycle performance. Another common misconception is that the output of LCA modelling is independent of geography and time. Variation in results contributes to another common misconception that if two models do not give the same results, then one or both models must be wrong, whereas in reality both models may be valid across different time/geography or may be valid for only one time or geography.

Next Don provided a brief overview of modeling tools that have been employed by different jurisdictions looking to advance LCFS-style regulations (Table 6). Don began with GHGenius, which was developed by the Natural Resources Canada and is the model used by the BC Government to support its RLCFRR analysis. Other models used include GREET (Argonne National Laboratory) and LEM (Mark Delucchi, UC Davis) in the US, and GEMIS, Gabi and SimaPro in Europe. Don noted that each of these models has its own strengths and weaknesses, as well as unique assumptions of geographies and time, which would explain the variation of tools available to regulators.

TABLE 6. LCA MODELS EMPLOYED BY CALIFORNIA, BC AND EU

	BC RLCFRR	California LCFS	EU RED
Model	**GHGenius**	**GREET**	**JRC/BioGrace**
Data Quality	Very Good	Average	Poor
Data Inputs	Actual values	Defaults	Defaults
Allocation	Follows ISO	Varies	Energy
Consistent	Yes	No	Yes
Complexity	Yes	Yes	No

Don noted that in the application of the LCA models to fossil fuels and biofuels, GHGenius, in his opinion, has the most robust dataset available. Moreover, in Don's opinion, the Western Canada dataset is better than the dataset derived by Central Canada LCA models, which in turn is superior to the dataset derived by US LCA models. Don cautioned that the EU RED uses outdated data/methods and excludes certain methods of oil extraction. As a result the EU RED model may not produce accurate outcomes. Lastly, Don shared his opinion that although the California LCFS co-product allocation is not consistent, the new GREET model data estimation approaches that are to become available next year, may address this issue. In the ensuing discussion, one workshop member noted that while the modelling methods may not be consistent, they may be nevertheless appropriate for the jurisdiction in which they are employed.

The application of LCA tools and processes to regulation, as well as to the ensuing challenges, was discussed next. The key challenge was data availability, which is considered problematic because companies are often unwilling to share their private information, for concerns relating to competitive value. As well, differences in LCA model design and treatment of complexities mean that fuels may be differently assessed across the range of models, which makes comparability a challenge. As general tenant, Don noted that the complexity can be addressed in part over time, provided feedback loops are built into the process. He added that users should not expect a model without feedback loops to provide correct outputs.

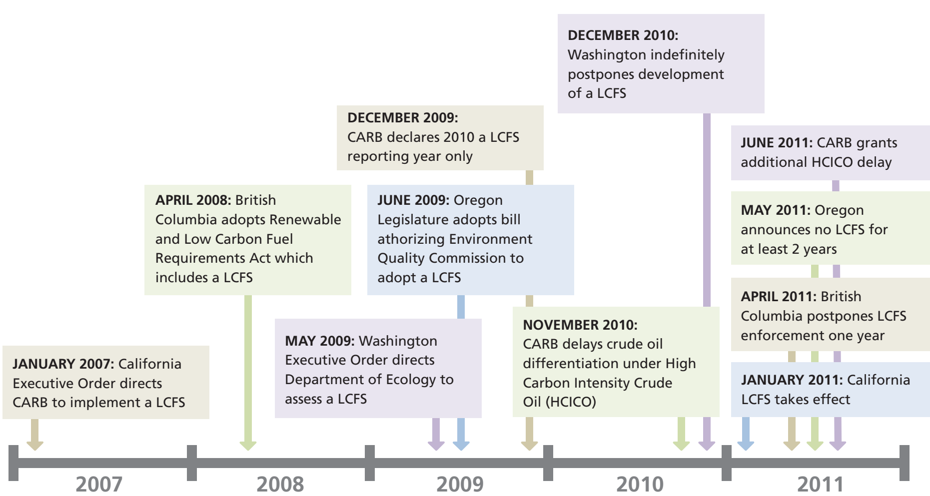
Don concluded his presentation by noting that LCA can be a powerful tool, with the capacity to address many of the issues present in LCFS. However, it is important to understand that none of the "good LCA tools" were originally designed for regulatory use, which creates challenges for both regulators and the regulated community. For example, the lack of high quality, timely data is, in Don's opinion, the biggest impediment to the application of LCA for regulatory use, but he concluded that of all of the jurisdictions using LCA in regulations, the data availability and quality were the best in BC.

5.2 Key Assumptions and Compliance Pathways for California LCFS

Catherine Reheis-Boyd presented an overview of the LCFS activity in California and the US RFS2 and its potential implications for crude oil supply in California and elsewhere. Catherine began her presentation with an overview of the California Air Resources Board's (CARB) initial statement of the reason for LCFS, which included the requirement to reduce GHG emissions from the transportation sector in California by about 16 million metric tons in 2020, to reduce California's dependence on petroleum, to create a lasting market for clean transportation technology and to stimulate the production and use of alternative, low-carbon fuels in California.

Catherine presented a chronology of developments in California's progress towards LCFS. She noted that the change in administration sees a continuance in the view to transform California's transportation system, but the post-budget process is not tied to any particular plan (Figure 66).

FIGURE 66. CHRONOLOGY OF LCFS DEVELOPMENT IN NORTH AMERICA



Bio notes: Catherine Reheis-Boyd, President, Western States Petroleum Association

Catherine (Cathy) Reheis-Boyd is the President of the Western States Petroleum Association (WSPA). Affiliated with WSPA since 1990, she currently directs WSPA's government affairs, assists the President in media affairs, oversees all office and committee operations, manages WSPA's staff and financial resources and provides strategic oversight of key issues. Prior to joining WSPA, Catherine was employed with Texaco, Inc.'s Bakersfield Division for seven years as an Environmental Regulatory Compliance Coordinator and worked for three years as an environmental consultant.

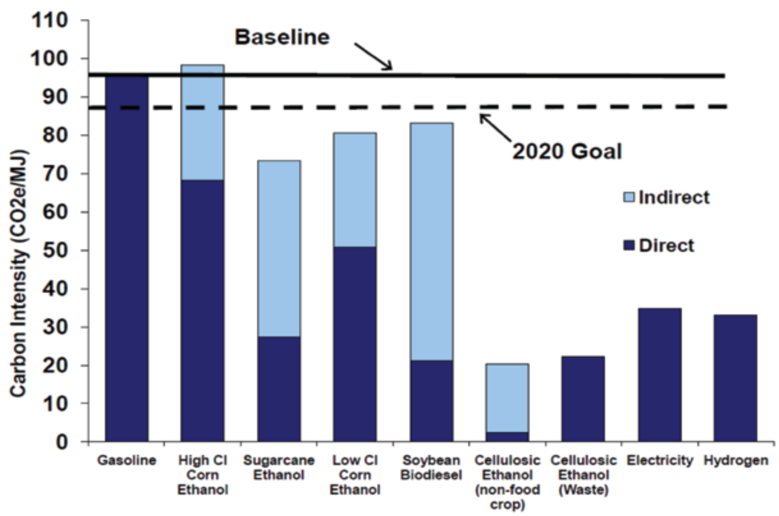
Catherine is a member of the California Chamber of Commerce Natural Resources and Policy Committee and was appointed by the Governor as a California petroleum industry representative on the Interstate Oil and Gas Compact Commission. She has chaired the Bakersfield Chamber of Commerce Air Quality Committee, and was past president of the Sacramento chapter of the Air & Waste Management Association. She has also served as past president of the Kern County Chapter of the American Lung Association, and received the Bureau of Land Management's State Director's Oil and Gas Award for Special Achievement.

Catherine is a graduate of the Bakersfield and California Leadership Programs. She received a Bachelor's of science degree in natural resource management from California Polytechnic State University, San Luis Obispo and pursued her post-graduate studies in environmental engineering at the University of Southern California.

Catherine noted that from 2009 onwards some states have delayed their LCFS processes because of numerous uncertainties with the policy

California has conducted analysis on the CI of a number of low-carbon options that will need to be considered if the State is to achieve its transportation emissions reduction goals. The options, illustrated in Figure 67, demonstrate that large differences in CI exist between corn ethanol versus electricity, hydrogen and cellulosic ethanol when indirect sources of carbon are incorporated.

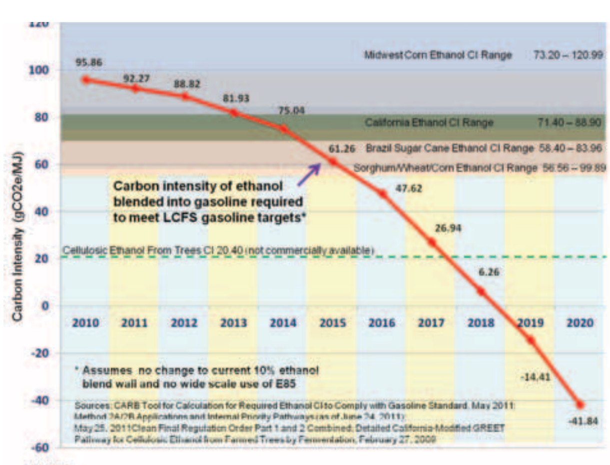
FIGURE 67. POTENTIAL LOW-CARBON FUEL OPTIONS



The difference in CI performance between non-cellulosic and cellulosic ethanol is the focus of the Renewable Fuel Standard Program (RFS2), which looks to significantly incent and increase the proportion of cellulosic ethanol available in the US by 2022.

Catherine then reflected on the California LCFS compliance schedule requirements that ramp up the reductions of CI of transportation fuels from 0.25 per cent in 2011 to 10 per cent by 2020. A review of CA's compliance pathway for gasoline illustrated timing challenges associated with current commercially available solutions (Figure 68).

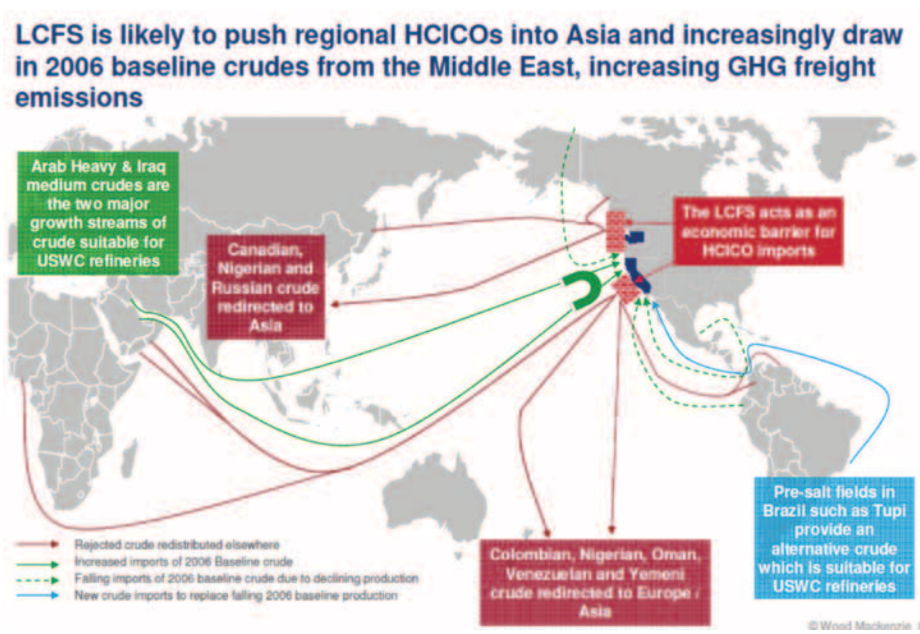
FIGURE 68. CI COMPLIANCE SCHEDULE UNDER CALIFORNIA LCFS



According to the estimates, 2015 will be a challenging year, when achieving compliance will become difficult unless efforts to increase access to other low-carbon sources, such as hydrogen and electricity, are made. To this end, timing is a critical issue for technology investment and capacity-building for the California LCFS compliance schedule. It is understood that after 2015, the State will have adopted considerably more biofuels, and will be looking to invest in electricity- and hydrogen-powered transportation systems. Who will supply the California market with these technologies and infrastructure – and at what cost – remains uncertain. Lastly, consumer preferences need to be considered, as individuals must purchase or lease these vehicles in large numbers to justify the fuel and infrastructure investments.

Next, Catherine introduced several dimensions of the California LCFS that are important to keep in mind relative to Canada's supply of crude oil to the state. First, diesel is an important issue that needs to be added to the discussion and California's provisions for HCICO. The industry perspective in California, which is based in part on a study by Wood Mackenzie, raises concerns over the effect that CI differentiation of crude oil could have on global emissions should crude shuffling result (Figure 69).

FIGURE 69. POSSIBLE PATTERNS OF CRUDE OIL SHUFFLING THAT COULD RESULT FROM LCFS IMPLEMENTATION IN WESTERN US AND CANADA



As the map illustrates, HCICO rules could force Canadian oil sands to travel much farther to markets, such as Asia, resulting in a net increase in GHG emissions as opposed to the decrease intended by the California LCFS. Such concerns about the overall effectiveness and efficiency of the regulation resulted in the creation a set of principles that were adopted by the Western States Petroleum Association (WSPA):

- Crude treatment must be practical, simple for regulated parties to use, and simple for CARB to enforce;
- Avoid an approach that encourages crude shuffling, and leakage of GHG and criteria pollutants;
- Avoid an approach that leads to increased energy security concerns/impacts;
- Do not disadvantage one crude oil relative to another;
- Provide for equal treatment of all refineries – including out-of-state and international refineries;
- Do not unfairly disadvantage one refinery relative to another based on that refinery's historical crude use;
- Provide a mechanism that is reasonable and consistent;
- Avoid difficulties and complexities regarding CI accounting of imports of products, intermediates or blend stocks; and
- Treat all CARBOB (California Reformulated Gasoline Blendstock for Oxygenate Blending) and all diesel equally with respect to credit/deficit generation regardless of crude source.

Catherine concluded that from WSPA's perspective, the California LCFS is a complex and cost-ineffective policy to reduce GHG emissions. On a cost per unit GHG emissions reduction, transportation fuel-related cost reductions substantially exceed the cost of other GHG emissions reductions. Furthermore, Catherine noted that if the policy goals are intended to promote biofuels or to electrify the fleet, direct and transparent regulations are better ways to meet these goals.

As with any new policy there is always the potential for unintended consequences, and the state or regional LCFS programs increase the risk of restricting transportation fuel supplies and of creating a competitive disadvantage compared to neighboring jurisdictions. These market effects could impact crude oil markets by lowering the supply of low CI biofuels to meet LCFS mandates, which may result in higher fuel costs while failing to reduce GHG emissions due to fuel shuffling – especially in the case of state or regional LCFS. Furthermore, LCFS that debit certain crudes (e.g., North American oil sands) may reduce energy security while actually increasing CO_2 emissions due to crude shuffling. An alternate perspective on LCFS that Catherine shared was to consider a policy directive that is driven more by **carbon efficiency** rather than CI.

5.3 Role of Information Science in Lifecycle Assessment as a Regulating Tool

Anil presented an overview of LCA, reinforcing several points raised during the previous presentations, before going into greater detail on the specific role that LCA has played in California. Anil then provided a more in-depth look into the process of engagement, information sharing, methods and compliance pathway development, as well as the approach taken to address uncertainty under LCFS.

Anil noted that LCA models have been the backbone in LCFS development to date, contributing to the estimations of CI of various fuels, as well as the calculation of direct and indirect GHG emissions. He also noted that as processes and technologies improve or new information becomes available, LCA models need to be updated and decisions on the subsequent regulatory revisions become necessary.

To start his presentation, Anil reminded that in California, direct emissions are estimated using the GREET model. To estimate indirect emissions associated with indirect land use changes (iLUC), the state utilizes a general equilibrium model called GTAP, which uses estimates from economic modelling, as well as emission factors, to quantify emissions from iLUC.

Anil noted that sources of uncertainty in the process of estimation are introduced at different stages in both the GREET and the GTAP models. For example, carbon loss \from soil and N_2O from fertilizer are sources of uncertainty in the estimation of direct emissions using GREET modelling. Estimating indirect emissions is even more challenging, as data availability, validity of parameters, and modeling constraints contribute multiple sources of uncertainty. In California, several activities are underway to address these challenges, including efforts to continuously improve the availability of data for better regulatory decision-making (for example, via mandatory reporting), the establishment of stakeholder engagement processes, the creation of the Expert Workgroup to provide technical advice and the introduction of the method 2A/2B applications. Anil then spoke to each of these activities.

Fuel suppliers in California report CI values information as well as carbon credits and deficits as a compliance obligation under the California LCFS. This information is then used to populate CARB's data inventory.

The stakeholder process encourages transparency on the part of government and provides industry with a mechanism to offer comments on new or revised regulations, methodologies and CI values for new pathways and sub-pathways, and to potentially challenge the analysis provided by regulators to attempt to address uncertainty or improve the approach.

Bio notes: Dr. Anil Baral, Senior Researcher, the International Council on Clean Transportation

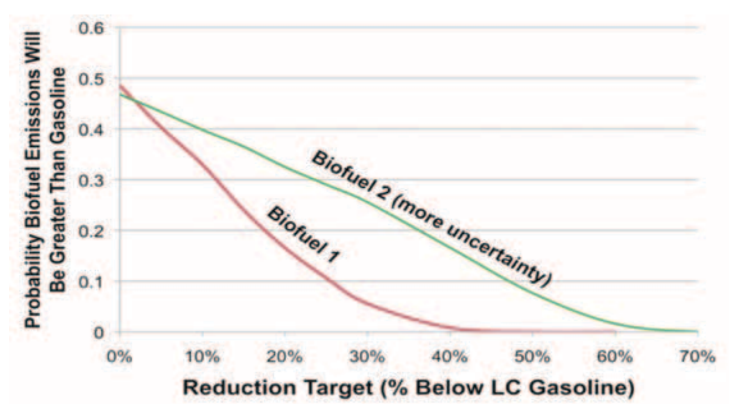
Dr. Anil Baral is a Senior Researcher at the International Council on Clean Transportation (ICCT) with expertise on biofuels/bioenergy, lifecycle analysis (LCA) and environmental policy. He has extensively published in peer-reviewed journals in areas of LCA, bioenergy and environmental policy. Prior to joining the ICCT, Anil was actively involved in developing a novel LCA tool called Eco-LCA at the Ohio State University. At the ICCT he works with regulators in the US and Europe assisting the formulation and effective implementation of low-carbon fuel policies and conducts research on LCA and low-carbon fuels. Anil previously worked as environmental coordinator at Martin Chautari, a non-profit organization, conducting research on electric vehicles and promoting alternative fuel vehicles in Kathmandu, Nepal.

More specific technical or policy issues are addressed through the Expert Workgroup, which is in Anil's opinion, an excellent source of challenge, correction and revision, in addition to frequent contribution of new sources of data and methodological insights to the LCA process. Anil shared that CARB is in the process of implementing near-term recommendations from one of the Expert Workgroup subgroups, which was formed to improve the understanding of iLUC science and data. Other tasks of the Expert Workgroup underway include: developing a spatially explicit set of carbon stocks and emission factors, developing an improved methodology for estimating productivity of new land, and re-evaluating elasticity and displacement ratios of corn and of dried distillers' grains with solubles (DDGS).[10]

Innovation and improvement activities have also been encouraged through CARB's approach to estimating fuel pathways and sub-pathways. Regulated parties may choose to use default fuel CI values provided by CARB for CI calculations, or propose their own values and seek CARB's approval for new fuel pathways or sub-pathways by providing evidence and data (method 2A). To date, approximately 60 applications have been made for registering new fuel pathways or sub-pathways with claimed improvements in CIs. The information accompanying new submissions helps CARB identify and understand new processes and technologies and to improve LCA estimates. Similar approach has been proposed for the HCICO screening process as well, where the regulated parties can determine whether their crude oil meets screening criteria (e.g., thermally enhanced oil recovery or bitumen) and either accept default values in the lookup table for HCICO, conduct LCA to prove it is not HCICO, or use method 2B and submit detailed evidence for approval of new CIs. Similar to the approach used for new pathways and sub-pathways noted above, this information enables CARB to continuously improve its working knowledge of CIs.

Lastly, Anil mentioned that sensitivity analysis and Monte Carlo analysis (a class of computational algorithm that relies on repeated random sampling) are utilized in some circumstances to address uncertainties under LCA (Figure 70). The choice of statistical tools used to perform this type of analysis is important, as a high degree of uncertainty for a new pathway could mean the difference between an improvement over gasoline or not. However, Anil cautioned that the use of single point estimates for analysis raises accuracy issues, and the question of how to address uncertainty in a more fulsome manner was left with the workshop participants.

FIGURE 70. UNCERTAINTY ANALYSIS OF MEETING CI TARGETS



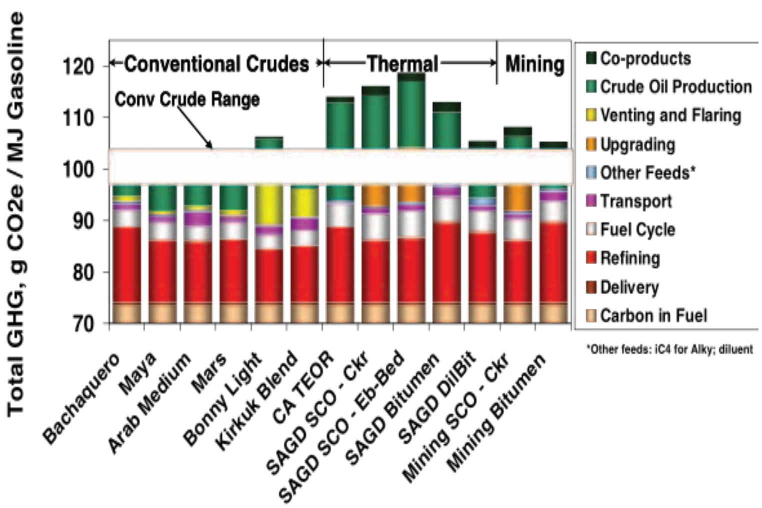
10 DDGS is a co-product of the ethanol production process, is a high nutrient feed valued by the livestock industry. When ethanol plants make ethanol, they use only starch from corn and grain sorghum. The remaining nutrients – protein, fiber and oil - are the by-products used to create livestock feed called dried distillers grains with soluble, source: **http://www.ksgrains.com/ethanol/ddgs.html**

5.4 Conventional Oil Baseline Emissions Estimates: Variability and Progress in Reducing Uncertainty

Adam Brandt presented an overview of the models that have been deployed to calculate conventional oil emissions, emphasizing the importance of accurate baseline emissions estimates. Adam's presentation also explored the importance of understanding and addressing uncertainties as a means of improving methodologies.

Adam began by describing the importance of using credible baselines to set targets to (e.g., 10 per cent reduction in transportation-related GHG emissions by 2020). He described the intricacies of the process to derive the baselines and to determine CI values for accurate analysis to support policy development. Using conventional oil and biofuel energy sources as an example, Adam explained that a significant variation in their respective CI values is due to differences across a wide range of variables (Figure 71). In case of conventional oil, these variables consist of the oil field quality (which is a function of the depth of the resource, size, age, pressure and crude oil quality); technologies utilized (for example, the injection of fluid or gas to enhance recovery) and different regulatory stringencies that can impose restrictions or limits on practices. Evidently, this complexity contributes to the variation in estimation methodologies and may result in uncertainties that may further impact the quality of the analysis.

FIGURE 71. JACOB CONSULTANCY LCA OF DIFFERENT CRUDE OILS DEPENDING ON SOURCE TYPE, CONDUCTED IN 2009



Adam discussed a number of previous efforts to assess conventional oil emissions, including the deployment of the GREET model for estimating alternative fuels emissions (see section 5.1 for additional information on GREET). In Adam's view, the tool, which was intended to represent industry-wide average conditions, relies on far too simple treatment of crude oil emissions, focusing on crude oil production and efficiency + fuel mix approach, with no specific treatment of oil production technologies.

Although a number of improvements were introduced to enhance the estimation of conventional oil emissions under GREET, including consideration of technology enhancements, the simplified approach, the narrow choice of projects and failure to utilize publically available data (the 'black box' problem, discussed previously) meant that the results were not illustrative of an industry average.

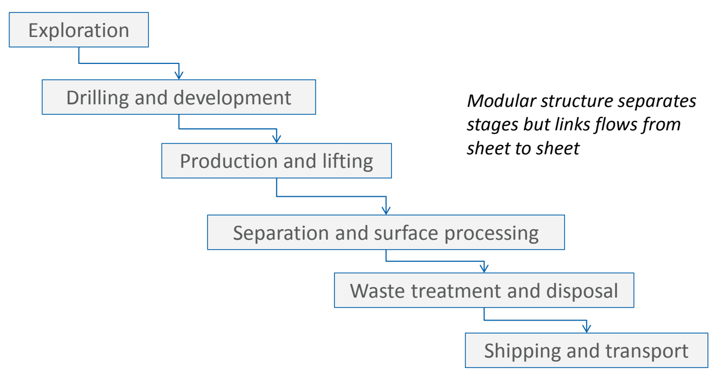
Bio notes: Adam R. Brandt, Acting Assistant Professor, Department of Energy Resources Engineering, Stanford University

Adam Brandt is interested in reducing the environmental impacts of energy systems. He studies greenhouse gas emissions from fossil energy sources with a focus on lifecycle analysis (LCA) of transportation fuels. Adam's current work focuses on baseline emissions estimation for petroleum production and in analyzing impacts from oil sands production and refining. Previously, Adam's work focused on oil shale, which is a low-quality hydrocarbon resource, resource depletion analysis and GHG mitigation through carbon dioxide capture and storage.

One other challenge noted by Adam includes the inability of model outputs to be verified or audited. Adam explained that stakeholders who cannot gain access to the information are unable to use or modify the information for guiding decisions. As noted in section 5.3, stakeholders looking to advance their own submissions under CARB's open methodology may be poorly informed and less able to advance thinking with limited access to the data and models. Adam also noted that the degree of access to data and assumptions is important to consider in a regulatory setting, where multiple stakeholders need to be able to view and challenge the information.

Next, Adam described the work, sponsored by CARB that is being undertaken to develop a public model that would assess GHG emissions from oil and gas operations. This engineering-based, bottom-up, LCA model is being designed to enable a user to plug in oil project properties and obtain GHG emissions estimates. The project, with research performed by Hassan El-Houjeiri, has five objectives: i) build a rigorous, engineering-based model of GHG emissions from oil production operations; ii) use disaggregated data; iii) use public data, where possible; iv) document sources for every equation, parameter and input assumption (no black box); and v) provide a model that is free to access, use and modify by any interested party. The model scope provides a visual reference of the lifecycle (Figure 72). Adam noted that refinery emissions are outside the model scope.

FIGURE 72. MODEL SCOPE



Adam noted that the model can be used for future California LCFS processes in a variety of ways, including a) more accurate calibration of crude oil baseline emissions estimates; b) more accurate accounting for the effect of changes in crude oil mix; c) screening and assessment of HCICOs; and d) the assessment of new crude oils or alternative technologies (used by the regulated parties).

The first version of the model is under development and is expected to be released in early 2012. It is expected that the model will undergo rigorous industry and peer review in the early 2012 and that the final model will be released by mid-2012.

5.5 Lifecycle Assessment of Oil Sands Technologies

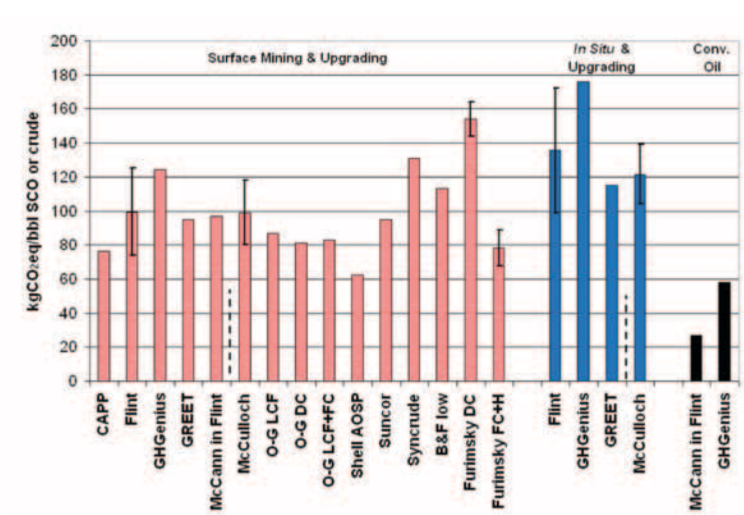
Dr. Joule Bergerson presented an overview of the insights gained from *LCA of Oil Sands Technologies* project (LCAOST) and discussed the potential issues and insights to be considered in the context of California LCFS. Joule began with an acknowledgment that the project is a joint initiative between the University of Calgary's Institute for Sustainable Energy, Environment and Economy (Dr. Joule Bergerson, Associate Professor and Principal Investigator and Dr. David Keith, Professor) and the University of Toronto (Heather MacLean, Professor).

To begin her presentation, Joule noted that the original motivation for the research in 2006 was to develop a lifecycle tool for the assessment of oil sands technologies. The tool needed to be able to inform oil sands operations, to incorporate the emerging technology evaluation and to assist with research, development and demonstration investment decisions. The lifecycle for the project would cover the full spectrum of well to wheel and include: recovery and extraction upgrading, refining, transport, and distribution and use in vehicle.

The motivation for the research changed in 2007, with the introduction of policies such as California's LCFS. California's policy innovation ushered in a number of changes in approach that fit directly with the objectives of the LCAOST, including the first-of-kind to use LCA to enforce policy. The LCFS, by definition, required more sophisticated tools and frameworks in order to determine CI and conduct comparative analysis. The development of a lifecycle tool for oil sands technologies could inform LCA-based polices, oil sands operations and investment decisions, emerging technology evaluation and R&D investments. As noted in section 5.4, a number of the research efforts that were being undertaken were not accounting for the differences in technology application.

A review of previous studies was conducted in 2009 (Figure 73), the results of which were presented by Joule, but no reasonable conclusions could be drawn from the work regarding the relative performance of the different categories of oil sands projects (in situ, mining) or of conventional petroleum. Questions also remained whether the full range of possible emissions had been captured and whether these were sufficiently robust across these models.

FIGURE 73. PREVIOUS WORK ON LCA OF OIL SANDS



Bio notes: Dr. Joule Bergerson, Assistant Professor, University of Calgary

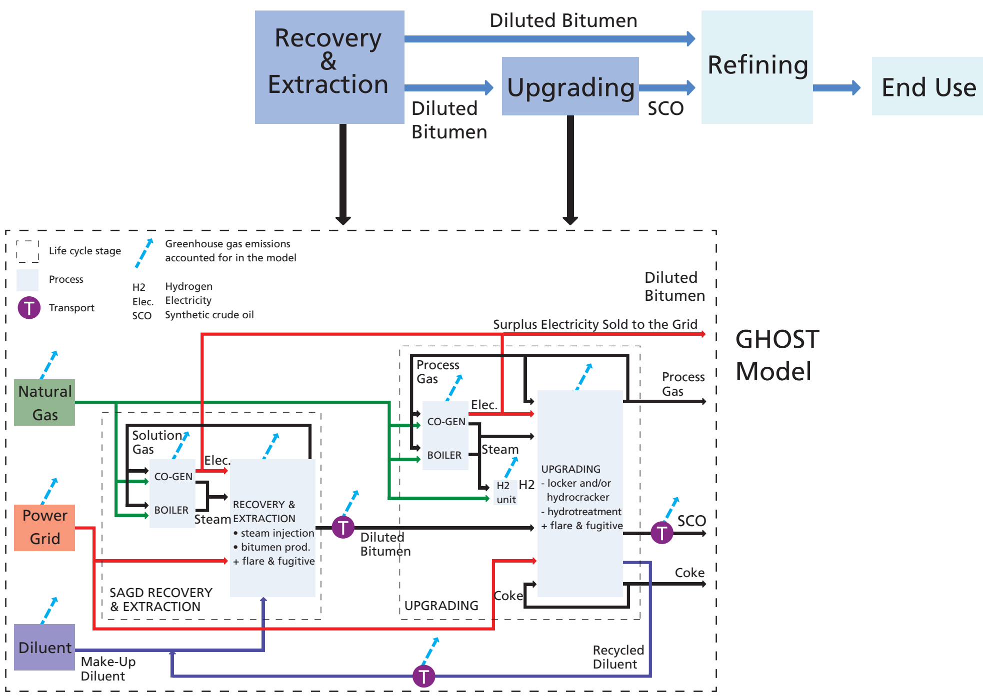
Dr. Bergerson is an Assistant Professor in the Energy and Environmental Systems Group and Chemical and Petroleum Engineering Department at the University of Calgary. Her primary research interests are systems-level analysis for policy and decision-making of energy system investment and management. The focus of her work is developing frameworks for the assessment of prospective technology options and their policy implications from a lifecycle perspective. To date, her work has addressed fossil fuel derived electricity, oil sands development and carbon capture and storage.

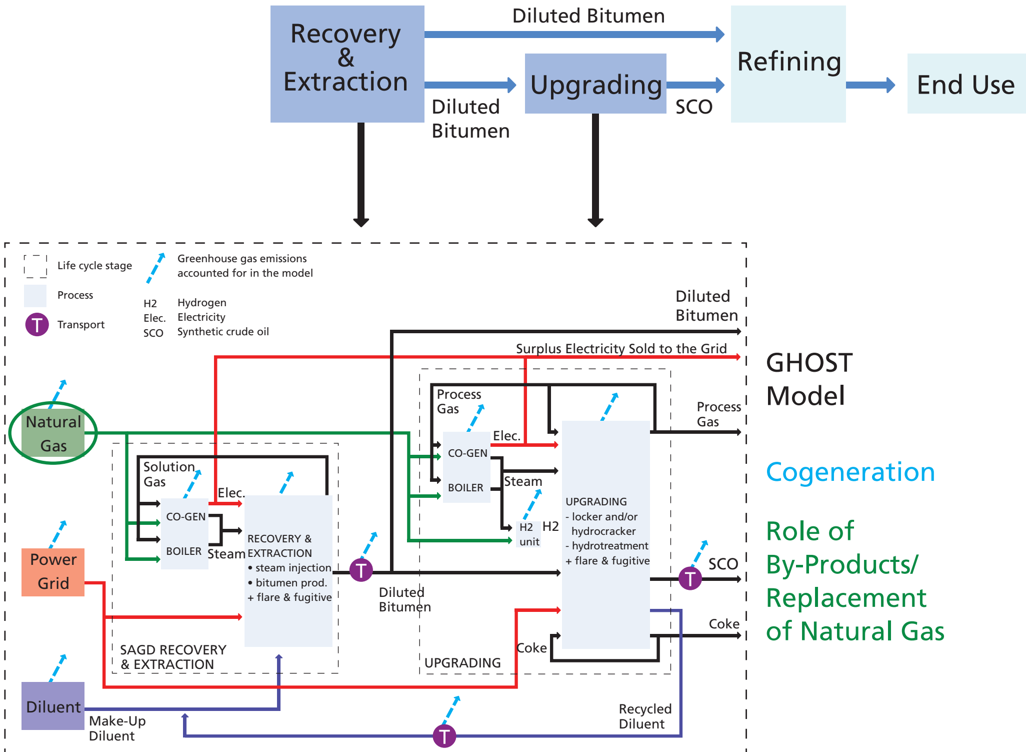
Joule received her Ph.D. in a joint program of Civil and Environmental Engineering and Engineering and Public Policy at Carnegie Mellon University. She has a Masters of Engineering Degree in Chemical Engineering with a collaborative program in Environmental Engineering from the University of Toronto and an undergraduate degree in Chemistry and Environmental Science from the University of Western Ontario.

The LCAOST project goals were specific to oil sands technologies and how they could contribute to reductions in GHG emissions. The goal was to characterize a range of existing technologies (not existing projects) and, similar to Adam Brandt's (section 5.4), pull in as much public data as could be verified so that the study would be relevant to the regulatory process while at the same time overcoming confidentiality issues. The team expected good data availability and accessibility, which led to difficulties, as this was not necessarily the case.

The team signed non-disclosure agreements to get operating data, and experts from industry and academia gave feedback on how these models and projects could be helpful. Joule noted that in their discussions, there was a tendency for participants to want to get a number for well to wheel GHG emissions per unit of transportation fuel when comparing oil sands to conventional oil. Joule presented the ranges between conventional oil and oil sands (unpublished) and noted that the range for oil sands was slightly wider and slightly higher than for conventional oil; however, there was a good deal of overlap in the two ranges (Figure 74).

FIGURE 74. GHOST MODEL (BASELINE EXTRACTION MODEL)



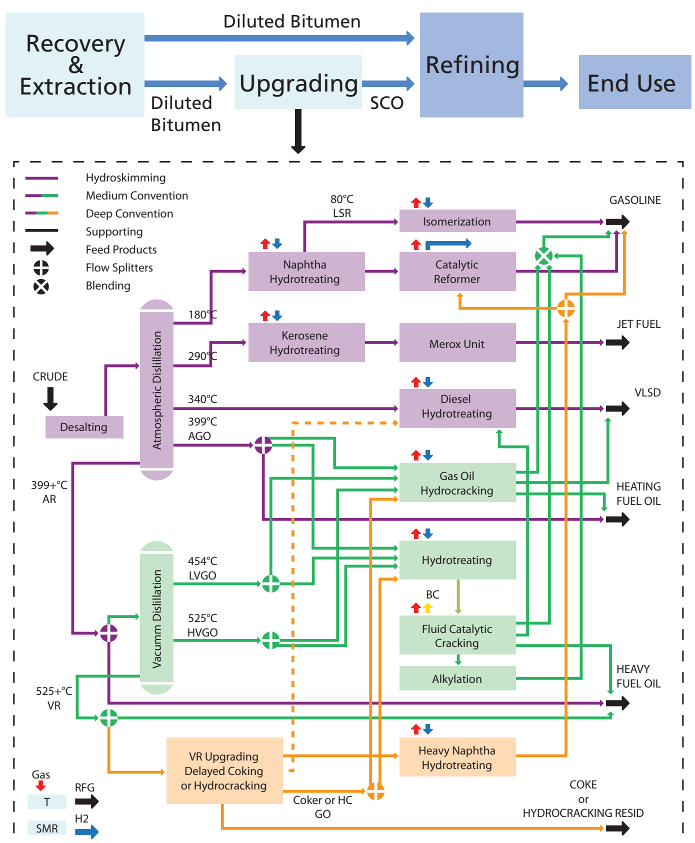


GHOST Model

Cogeneration

Role of By-Products/ Replacement of Natural Gas

Refinery Model



Next, Joule discussed the GHOST Model, or Baseline Extraction Model, that has been created by Alex Charpentier. The model is an Excel-based software tool that characterizes energy use and GHG emissions associated with existing oil sands technologies. It explores ranges of key parameters, which have been informed by public data (EIAs, Sustainability Reports, ST-43 etc.), and is supported by a bottom-up data-driven effort (data obtained under NDAs with oil sands companies), which includes direct industry feedback on reasonable ranges for each parameter.

One of the conclusions from the LCAOST was that assigning one value for the entire range can be problematic as it does not tell the individual story of those facilities and technologies that are at the lower end of the oil sands performance range. Joule posed the question of whether there should be a mechanism that rewards the higher emissions producers to reduce their emissions.

One of the storylines that emerged from LCAOST was the application of cogeneration; namely, steam and electricity that are both required for oil sands. Many oil sands projects have the ability to produce surplus electricity that could be sold into Alberta grid, which could lead to emissions obligation reductions. The application of cogeneration technology by some companies is making a difference in their emissions profile and was identified by the LCAOST research initiative.

Another important finding from the initiative was that the differences in accounting methods used to analyze emissions can significantly influence the results. This is an observation that was discussed by previous presenters (see section 5.1, 5.3 and 5.4)

Joule noted from the conclusions of this work that the oil sands pathways provide unique challenges in lifecycle modeling and that some of these challenges have yet to be taken into account in current LCFS policy work. The ranges of emissions should be considered, even if there is no distinction between crudes. Based on the research findings, there is a potential for unintended consequences if these factors are not taken into account. Some of the remaining questions that arose over the course of the work included:

- How do we deal with variability in oil sands pathways and with innovations that reduce emissions?
- How do we harmonize LCFS across North America? What are the implications of not doing this?
- What are the penalties for non-compliance going to be, and are they severe enough to satisfy the goal of LCFS?

Joule shared that her future work will investigate emerging technologies.

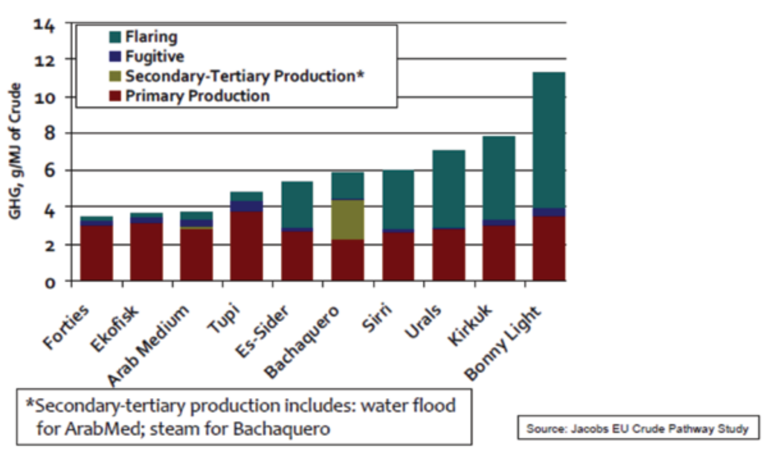
5.6 An Alberta Perspective

To conclude the session, Chris Holly presented an overview of a number of issues and perspectives that the BC RLCFRR is raising in Alberta, and discussed the role and challenges associated with LCA and its application to crude oil production.

Chris began his presentation by providing context around the importance of Canada/Alberta's crude oil production, noting that Canada is one of the world's largest oil producers and one of the few countries with a growing oil production. In recognition of its global role in oil production, Alberta has taken steps to advance resource development and environmental policies, and to establish an open and transparent arms-length environmental regulatory system. Chris noted that energy is a complex policy area that requires its own sound technical work and a clear understanding of markets. To this end, Alberta Energy Research Institute (AERI) released a number of LCA technical assessments conducted by Jacobs Consultancy Canada Inc. and TIAX LLC that compare GHG emissions from the oil sands derived crude oils to conventional oil production.

Chris noted a number of key messages that arose from these assessments. First, that the oil sands are not a type of crude oil; rather, the oil sands are an oil development area. GHG emissions from crude oil production depend on the type of energy used to produce crude, the amount of gas flared, and fugitive emissions, among other things. All crude oils fall on a continuum of GHG emissions-intensity associated with their origins, production and refining processes (Figure 75 and Figure 76).

FIGURE 75. EXAMPLES OF VARIABILITY IN CRUDE OIL PRODUCTION CARBON



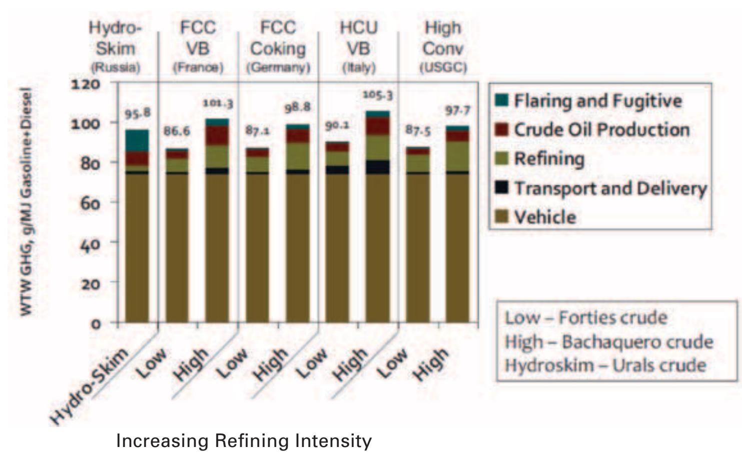
Bio notes: Christopher J. Holly, Branch Head, Research and Technology Branch, Energy Policy and Research Division, Alberta Department of Energy

Christopher Holly is the Branch Head, Research and Technology Branch, Energy Policy and Research Division of the Alberta Department of Energy. Prior to becoming Branch Head, Research and Technology Branch, Christopher was the Issues Manager, Oil Development Division of the Alberta Department of Energy. Chris has a diverse background in public energy policy development dating back to the 1970's. Through his extensive experience, Chris has been involved in a wide range of energy policy areas, including nuclear energy, energy efficient housing, industrial energy conservation and energy efficiency, renewables, alternative transportation fuels, power generation (coal, cogeneration, wind, hydro, solar, biomass), electricity deregulation, heavy oil, oil sands, economic and value added development and royalty.

Chris is also an ongoing guest lecturer on royalties and resource development for various institutions, including the Government of Alberta's Executive Management Programs, the University of Alberta's Centre for Applied Research in Energy and the Environment (CABREE) and the Canadian Petroleum Institute.

He graduated with a BSc (Physics) from the University of Alberta in 1983, obtained a Diploma in Public Sector Management from the University of Victoria in 1985, and completed a Masters in Public Administration from the University of Victoria in 1987.

FIGURE 76. EXAMPLES OF CI OF GASOLINE AND DIESEL DEPENDING ON REFINING COMPLEXITY



Second, Chris noted that the scope and intentions of modeling efforts in LCA often depend on the allocation of co-products. Therefore, it is important to understand the primary motivations of different jurisdictions, because it provides context to assessing the LCA models used, their design and the outputs. Examples of varying objectives include carbon management, going 'off oil', farm support, local and regional economic development and trade protectionism.

Third, research design (pattern- and hypothesis-based) considerations are also important to address as part of LCA modeling efforts. For example, pattern-based research design looks at statistical significance within data; vis-à-vis hypothesis-based research design relies on testing a proposed explanation of a phenomenon. Consequently, the GHG effectiveness may vary based on the model construct.

As noted in previous presentations, Chris mentioned that there are concerns with variability in LCA results. He cited multiple causes for the variations to exist, including:

- Data: outdated, misinterpreted, selective or comprehensive; varied nature and scale of uncertainty
- Administration: complexity vs. simplicity/verification
- Accounting: verification and financial settlement
- Market response: crude/refining shuffling, crude production base, consumption changes
- Performance measurement: data uncertainty > performance target

Chris noted that 80 to 85 per cent of GHG emissions are attributed to conversion of fuel to work, fuel pathway energy and material balances and fuel consumption; only 15 to 20 per cent are attributed to upstream crude production, crude transportation, refined petroleum products (RPP) production and retail delivery.

To close the presentation, Chris re-stated the importance of examining specific low-carbon policy objectives, selecting appropriate research design and addressing data uncertainty and performance measurement concerns. Lastly, Chris mentioned a number of AERI research studies that are pending:

- EU crude study
- Biofuels pathway study
- Fuel energy densities studies

These studies will continue to inform and improve LCA modelling efforts, and are part of a broader effort underway in Alberta, Canada and internationally.

Chapter 6: Moving Forward with LCFS in BC: Priority Issues to Be Addressed

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Chapter 6: Moving Forward with LCFS in BC: Priority Issues to Be Addressed

Following the opening plenary on the morning of Day 1, the workshop agenda moved into a set of parallel sessions, as detailed in the previous three chapters. The respective themes of the parallel sessions were (1) Policymaking and Regulation, (2) Vehicle Fuel System and Powertrain Technologies and (3) Lifecycle Analysis (LCA) and Regulatory Information. Each of the workshop participants selected a parallel session to attend. Thus, as Day 1 of the workshop drew to a close, each of the thematic areas and the associated issues were well understood by roughly one-third of the participants, but not necessarily by the other two-thirds.

To expose all of the workshop participants to the issues emerging from each of the parallel sessions on Day 1, and to foster cross-examination and dialogue on priority issues to be addressed in the BC RLCFRR, Day 2 shifted to a series of rotating breakout sessions. The participants remained grouped as in Day 1, but they were now asked to discuss and identify the critical issues arising from the content presented during the plenary sessions and in their respective parallel sessions from the previous day. Specifically, each group was charged with composing a list of approximately 10 issues, questions or findings that they felt reflected their dialogue. It was not required that the items listed reflect consensus among the group, but the participants were asked to identify where there was convergence of opinion, and where divergence was present, ideally to provide an explanation of why.

Upon completing their lists, the groups were directed to "rotate" through two sequential breakout sessions in which they were asked to review and consider the priority lists composed by each of the other two groups. To ensure continuity and relevance of the dialogue in the breakout sessions, and to provide expert advice and input, the speakers from parallel sessions on Day 1, as well as the session facilitators and scribes, remained in place with their lists, while the three separate groups rotated through their respective rooms and thematic areas. In this way, each of the three participant groups had the opportunity to review, discuss and modify (where appropriate) the priority lists relating to each theme. This format served the following purposes:

1. Participants were able to view and contribute to the issues, questions or findings that emerged from each of the thematic areas, including the differences and similarities between these areas;
2. Participants had the opportunity to interact with all the presenters, and thus gather a broader perspective on the LCFS than if they had remained in only one thematic area;
3. Cross-pollination across thematic areas was made possible; and,
4. Each of the lists was improved upon through the contributions of the rotating groups.

Content was added to the lists but not removed, although the list elements could be reordered. The session facilitators were responsible for maintaining the integrity of the lists and for managing group discussion, wherein new issues were identified and clarification added. In this way, the final output lists reflected the collective input of the workshop participants, and their perspectives. These lists are presented below as they were presented to plenary at the end of the workshop agenda (with a very light degree of editing for clarification). It bears repeating that these lists do not reflect consensus among the workshop participants and, given the size of the group, their contents may be biased toward the input of more outspoken participants.

Policymaking and Regulation – Assessing LCFS and Other Policy Frameworks in a BC Context

Critical issues and priority areas to address under LCFS

1. There are divergent views on the efficacy of LCFS to reduce the CI of fuels and to contribute to GHG emissions reductions.

2. LCFS may not be the most effective policy mechanism to achieve all the objectives and targets (related to emissions reductions for transportation fuels). A look at other policy strategies to achieve specific goals is needed, such as "drop-in" biofuels, improving refinery efficiencies and growth in alternative energy and technology.

3. An array of options exists to reduce GHG emissions from transportation, aside from measures to reduce the CI of transportation fuels.

4. Existing compliance pathways may not be adequate over the 2012 – 2015 period, and beyond 2015 no demonstrable, transparent pathways exist to meet the target. A need exists for strong market signals and policies to incentivize alternate pathways.

5. There could be benefits to harmonization and consistency of policies and methodologies (e.g., CI, iLUC, HCICO, sustainability criteria) across regions (i.e., North/South; East/West) to avoid "fuel shuffling" or "crude shuffling" and potential (and unintended) economic disadvantage.

6. Successful policy must incent development of biofuels, new alternative fuels and alternative technologies at sufficient scale and pace to meet targets as currently defined. The consumer (i.e., the end-user) must be incorporated into the overall strategy, to align market demand with the introduction of low-carbon fuels and transportation technologies.

7. A need exists for clear and transparent policy and regulatory certainty and stability with realistic and achievable outcomes in order to attract investment and avoid stranded assets. "Off ramps" (e.g., alternative compliance mechanisms) can create uncertainty (presuming some level of prior certainty exists).

8. Debate around crude differentiation needs to be addressed as CI of petroleum has a significant impact on compliance (e.g., "basket" approach vs. CI by crude type).

9. iLUC and indirect impacts of all fuels need to be better understood (based on the weight of scientific evidence) and, if significant, need to be incorporated in the rulemaking.

10. The bulk of emissions occur during the combustion of liquid fuels. Well-to-tank emissions are within the control of the obligated parties, but tank-to-wheel emissions are beyond the traditional scope of the core business activities of fuel suppliers. It is a challenge for industry to develop compliance paths outside their traditional business model.

"Low-Carbon" Vehicle Fuel System and Powertrain Technologies

Critical issues and priority areas to address under LCFS

1. Review past experience in North America and in other jurisdictions regarding the introduction of new technologies, current technological developments and the evolution of market drivers, and then evaluate what has been learned. For example, compared to some markets, North America has been slow to adopt natural gas-powered vehicles (NGVs). Previous efforts to introduce NGVs into North American markets were unsuccessful (due to a combination of consumer acceptance and economics). Currently, there are fewer incentives in Canada than in the US (e.g., Quebec is the only province with an accelerated capital cost allowance write-off for NGVs).

2. To expand the use of alternative fuel vehicles in transportation, it would be important to address fuelling infrastructure issues. Policy directed to address specific infrastructure barriers would be most effective. Liquid fuel producers must supply a fuel compatible with the evolving fuel and retail distribution infrastructure and vehicle fuel systems, keeping in mind that the average age of vehicles on-road and in-service in BC is 7-8 years, and newer vehicles are expected to last 10-15 years before replacement. Liquid low-carbon fuel must be compatible with existing gasoline and diesel vehicles, unless new infrastructure is provided.

3. There is an issue related to coordination of policy to address the transportation sector as a whole. Presenters commented on the current proportions of GHG emissions due to fuel usage (i.e., the emission split was accepted by some to be 22 per cent in production (well-to-tank) and 78 per cent in combustion (tank-to-wheel). The key policy point is that producers cannot come close to meeting the target solely by focusing on upstream activities. Conventional hydrocarbons need to be substituted by lower carbon fuels to achieve targets. The 78 per cent due to combustion is being addressed through other policies.

4. Additional flexibility mechanisms for compliance should be investigated as part of the LCFS.

5. Regulations will be more effective if they are clear and reasonably certain, and should consider issues of alignment among related jurisdictions. A short-term challenge to meeting the RLCFRR reduction goals is the supply of low-carbon fuel alternatives. Long-term challenges will relate to incremental change versus transformational change, and will LCFS continue to be one tool among others?

6. Adjusted for inflation, fuel prices today are near an all-time high, but real driving costs are still low due to vehicle efficiency improvements. The real cost of driving may continue to drop, as vehicle efficiency continues to improve. Consumers will not drive demand in technology/fuel choice. Most consumers are risk-averse and work with an average three-year payback period. Policies which directly address the consumer barrier may be needed.

7. LCFS will have tax revenue implications that governments must consider.

8. Upfront capital cost is a big barrier (related to EV use) for the consumer, along with range and recharge performance. However, BC has one of the highest price differentials between gasoline (higher) and electricity (lower) in Canada, such that avoided expenses on gasoline could offset some or all of the upfront costs. How can economic value of the long-term energy savings be used to overcome the short-term capital cost barrier?

9. Clarity is required as to whether carbon credits due to EV usage would accrue to EV owners or the utility provider. Credits accrue to those first entering the market. The BC Government seeks to facilitate credit trading, as potential buyers and sellers have not yet found each other. This structure does not address the consumer cost acceptance issue. Credit to the supplier does not address the consumer's behaviour.

10. Synthetic fuels can be produced from low-carbon, renewable energy resources that would not normally be used, and these fuels can be converted to fungible fuels (i.e., compatible with current infrastructure).

11. LCFS may not have an impact on powertrain technology, but powertrain technology will have an impact on the effectiveness of LCFS. Differing views exist on this assertion. Evaluate drivers and policies that improve drivetrain technologies.

12. Cleaner fuels to enable the introduction of advanced powertrain technology and exhaust after-treatment devices may conflict with LCFS and other related policies.

13. Examine policies that complement and support the LCFS.

Lifecycle Analysis (LCA) and Regulatory Information

Critical issues and priority areas to address under LCFS

1. Multiple LCA models are available to regulators, each with strengths and limitations. Regulators should recognize the limitations of these models when they consider outputs to apply to policymaking. Regulators need to pick one tool for their jurisdiction and apply it for all parties. There may be concerns about the availability of data between competing entities due to disclosure issues.

2. The LCA tools were not designed for use by regulators, initially, but in recognition of their usefulness, improvements are being made in a number of jurisdictions. Models need to be transparent and science-based. Is there room for cooperation or harmonization on methodologies? What do we do in the absence of harmonization among jurisdictions? Specificity on tools is needed, going forward, to reflect regulatory drivers (e.g., one value versus a range of values). Peer reviews should be required for new data and processes in order to modify assumptions. Standardized processes must include any changes or updates to the model, which may require changes to the regulation. There can be a financial impact if LCA tools, as they evolve, require existing processes or facilities to change, so transparency between the regulators and regulated entities is required. Once a tool or model has been used by regulators and regulated entities to determine and quantify a specific fuel LCA value, it should be applied as the default value for the facility (e.g., "grandfathering").

3. Need to innovate and improve within sectors as opposed to only focusing on comparisons between groups (e.g., oil sands technologies: how can they contribute to reduction?). This would be reflected for all fuel types. There are implications for reporting that should be considered. Is point-source regulation more appropriate than LCA for effective GHG emissions reductions in the jurisdiction where the emissions occur?

4. Allocations made under LCA models matter to the CI outputs. In particular how allocations are assigned to by-products and co-products of fuel production processes can influence the outcome of LCA. This can cause significant sources of variability among models, which needs to be addressed in the context of evaluating CI reductions now and in the future.

5. Data availability and quality issues are critical to address, as they can influence policy decisions in significant ways. The maturity level and methodology of the LCA models need to be taken into consideration for all data results and interpretation of those results. The noise may be overwhelming the signal.

6. Where should LCA focus with regards to the greatest reduction of GHG emissions: refining or lower in the supply chain (i.e., at the vehicle)? Does limitation of focus on the upstream *limit* potential GHG emissions reductions overall?

7. Can LCFS be expanded to account for fuel efficiencies in vehicles (i.e., gCO_2/km)? LCA models account for this, but LCFS does not give credit for it.

8. What is the measure of success from LCA with respect to LCFS? Overall GHG emissions reductions, or lowered CI? Is there an expectation to affect jurisdictions outside of the regulated entity? A higher level of clarity on the motivation underlying LCFS is needed.

9. Should the LCA tools be used for LCFS with regards to new technologies and processes versus a sole focus on existing, commercially available products and processes?

Chapter 7: Recommendations for the Future of LCFS in BC

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Chapter 7: Recommendations for the Future of LCFS in BC

The previous chapters present a detailed review of the potential implications of the LCFS as it is implemented in the province of British Columbia. The broad range of perspectives shared at the workshop are captured and reported in these chapters, as are the priority issues identified by the workshop participants.

This chapter proposes guiding principles and recommendations for the future of the *Renewable and Low Carbon Fuel Requirements Regulation* (RLCFRR) in BC. While these submissions are *informed* by the workshop dialogue and by input from the Advisory Group, they are *solely* the product of Pollution Probe's evaluations, and they do not necessarily represent the views or positions of the workshop advisors, presenters or participants.

Guiding Principles

- ***Net global* reductions in GHG emissions should be an outcome** of a well-designed and implemented policy framework to address climate change. Thus, the contributions of the RLCFRR to GHG emissions mitigation should be reasonably demonstrable. By contrast, if actions taken to reduce BC's transportation-related GHG emissions result in an offsetting increase in GHG emissions in other sectors of the economy or in other jurisdictions (i.e., "crude shuffling"), then the policy should be re-evaluated.

- **Sustainability should not be sacrificed in the pursuit of GHG emissions reductions.** The RLCFRR focuses on reducing the carbon intensity (CI) of transportation energy, but the sustainable use of land and water is also important to holistic environmental policy. The ongoing evaluation of the RLCFRR must consider the implications beyond mitigation of GHG emissions.

- **Clarity on the role of government.** Tackling issues as complex as climate change and sustainable development will require actions on the part of numerous organizations in both the public and private sectors. Government policy will play a critical role in driving change, as well as enabling change led by non-government entities. If government regulation obligates the private sector to innovate new technologies and business cases, then government should clearly define its role and the nature of its responsibility in creating the conditions for successful compliance.

- **Evaluation and continuous improvement** are important commitments, particularly considering the innovative nature of the RLCFRR and its relatively recent introduction. BC and California have already conducted interim evaluations, and California has committed to an additional evaluation period in the future.

- **Transparency** regarding the objectives of the RLCFRR in BC was called for repeatedly at the workshop. This includes access to data, information, analysis, rationale, as well as to ensure there is a clear and credible compliance pathway to 2020 and beyond. Transparency, for example, is important to understanding whether alignment with the objectives of the California LCFS and EU Fuels Quality Directive is the objective of the BC RLCFRR policy, or a feature of the policy to enable compliance.

- **Policy effectiveness** is an important tenet to ensure that the correct tool(s) is used to achieve GHG emissions reduction at lowest cost to government, industry and the public. This is an important consideration in coordinating among policy instruments within a jurisdiction, and across jurisdictions (e.g., harmonization). There are two important ways in which this principle should be expressed:

- **Verification of compliance pathways** is a critical source of planning for government and industry. An open source for compliance pathway analysis is critical to drive investment and, ultimately, achievement of the RLCFRR objectives.

- **Commitment to tangible progress** requires that a lack of information is not a rationale for inaction. Where critical information is not available or otherwise unreliable, actions to address the knowledge gaps should be undertaken, possibly as a joint effort by regulators and obligated parties alike.

Expansion, clarification and ratification of proposed principles could be the subject of future dialogue between industry and government.

Recommendations

Pollution Probe exists to improve the health and well-being of Canadians by advancing policy that achieves positive, tangible environmental change. Government is solely responsible and authorized for establishing public policy. Therefore, Pollution Probe focuses its efforts on informing and supporting the policy development process led by government. In the context of the RLCFRR, Pollution Probe sees three distinct options for the BC Government to pursue:

1. Stay the course on the RLCFRR but modify aspects of the regulation to address legitimate issues.
2. Shift focus to other GHG abatement efforts.
3. Bridge from RLCFRR as regulation to a more comprehensive strategic framework, inclusive of several complementary policies and measures to reduce emissions from transportation energy use.

Recommendations for each of these options are presented below.

1. STAY THE COURSE

The scope of transformation that must occur in the way transportation energy is supplied and used, ranging from infrastructure to technology to business models, to comply with the RLCFRR targets in 2020 (and for targets set in the years beyond) exceeds the capacity of conventional regulation. Neither government nor industry specified a compliance pathway to the current RLCFRR 2020 targets in the workshop presentations or dialogue. Therefore, careful consideration should be given to modifying the targets and expanding the flexibility mechanisms under the compliance structure.

Recommendation: Maintain a renewable fuel content requirement in gasoline and diesel in the 2020 timeframe. This will help to sustain the demand for renewable fuels in BC and encourage continuing investment in production capacity and in R&D in the sector. This is important, particularly if flexibility mechanisms to facilitate CI compliance under the RLCFRR serve to diminish demand for "drop-in" biofuels. The requirement should be informed by periodic assessments of the technologically feasible levels of marketable supply.

Recommendation: Establish a single reference case against which progress toward CI compliance is measured. This reference case should represent the combined sales-weighted average CI of gasoline and diesel in the base year. This could potentially embed a market preference for diesel over gasoline in the province. While this can contribute to the CI reduction of transportation energy in BC, overall, the potential implications of this shift (i.e., particulate matter air pollution; demand for biodiesel over ethanol as blend stock) must also be monitored and managed. Unintended changes to the competitive landscape may also result, impacting some fuel suppliers negatively, while benefiting others; these changes should be considered and addressed.[11]

Recommendation: Monitor and measure changes in vehicle powertrain efficiency in the province for the purpose of updating the Energy Efficiency Ratio (EER) factor used in the CI calculations for different fuel pathways. Powertrain efficiencies are evolving rapidly, partly due to federal GHG emissions regulations on light- and heavy-duty vehicles, and this can have a substantial influence on the lifecycle emissions associated with conventional fuels, such as gasoline and diesel. These efficiency improvements should be reflected in the LCA model used to determine the CI of fuels sold in BC.

Recommendation: Consider the evaluation and assignment of credits towards compliance for investments made by obligated parties (and their agents) in low-carbon transportation energy distribution infrastructure and technology in the province. This would not necessarily equate to reductions in CI of fuels sold in BC within the 2020 timeframe, but it can make meaningful contributions towards achieving the objectives of RLCFRR by building capacity and creating the conditions for transformation to a low-GHG transportation future. Efforts to ensure that allocations of such credits are grounded in viable business cases that generate returns on investment will minimize the risk of stranded capital, and enhance the value of the credit.

Recommendation: Dedicate resources to complementary measures that strongly support the achievement of the RLCFRR compliance among fuel suppliers, such as investments in low-carbon fuel alternatives, advanced technology Research, Development and Commercialization (RD&C) and enabling fuel storage and distribution infrastructure. Alignment on technology, infrastructure and price is necessary to enable market transformation. Examples exist in the province's support for electric vehicle (EV) and liquefied natural gas (LNG)-powered tractor use, as well as hydrogen fuel cell R&D.

Recommendation: Consider changes to the CI targets or the timeframes that would align with identified compliance pathways, and with applicable compliance flexibilities under the RLCFRR.

11 Market disruption, after all, appears to be an unavoidable consequence of RLCFRR, since the objective is to force technological transformations away from the prevailing sales mix of gasoline and diesel in the province, to lower-carbon alternative fuels and transportation technologies.

2. SHIFT FOCUS TO OTHER GHG ABATEMENT EFFORTS

It may happen that, at some point in the future, administrating and enforcing the RLCFRR encounters barriers that cannot be resolved. These barriers could be technological, economic, social or political in nature. Currently, the RLCFRR is the central instrument of policy that the BC Government is using to drive transformation of the transportation energy system, but it is not the only tool that government can use to achieve its goal. Targeted measures to promote the development, deployment and market adoption of advanced renewable fuels, natural gas-powered vehicle technology, EV technology and fuel cell technology, can support the diversification of transportation energy systems. As well, a range of measures to promote general improvements in the efficiency of gasoline and diesel vehicle operation were also identified throughout the workshop.

Recommendation: Maintain a renewable fuel content requirement in the gasoline and diesel pool. Consider a schedule of declining CI targets for the renewable portion of fuel blends to motivate the development and commercialization of "next generation" biofuels. This could help deliver reductions in overall CI even if blending volumes cannot be increased.

Recommendation: Investigate the potential comparative advantages to the end-user of using alternative fuels and advanced technology vehicles and, where possible, means of enhancing their value proposition to the market. Appropriate actions could include collaboration among government, regulators, energy companies and transportation technology providers and manufacturers to innovate business models that unlock the value of new, low-carbon transportation energy solutions.

Recommendation: Consider financial incentives that accelerate market uptake of highly fuel efficient vehicle models and advanced fuel-saving technologies.

Recommendation: Make industrial freight transportation a priority of the government in terms of reducing fuel consumption and GHG emissions. Federal regulations on GHG emissions from light-duty vehicles will mitigate demand for gasoline, but demand for diesel is expected to grow. Therefore, policies that enable more efficient movement of freight and the use of lower carbon fuels in the heavy-duty sector should be encouraged (e.g., LNG-powered tractor technology). Investigations into the duty-cycles of BC tractor-trailer operations should inform the development of targeted measures to promote the use of effective fuel-saving features (i.e., aerodynamic enhancements, low rolling resistance tires, advanced transmissions), and that enable efficient practices, such as the use long combination trailer configurations, where safe and appropriate.

Recommendations: Utilize the price signal inferred through BC's carbon tax by aligning it with the carbon intensity of fuels sold in the province. This will help to advance process efficiencies in the fuel refining and fuel distribution sectors in the province.

3. BRIDGE FROM LCFS AS REGULATION TO A MORE COMPREHENSIVE STRATEGIC FRAMEWORK

Pollution Probe believes that regulation, in the traditional sense, will be insufficient to carry the scale of energy system transformation that is the objective of the RLCFRR in BC. Rather, this objective requires a comprehensive strategic framework populated by a range of tactics and measures, some of which are driven by government policy while others rely on voluntary initiatives on the part of private sector industry. The vision that sets the parameters of the strategy *can* be consistent with that of the RLCFRR, but, rather than focusing on *carbon intensity* of the transportation energy system in BC, the focus should be on the *climate impact* of transportation energy use at a global level.

The climate impact of transportation energy use derives from many determinants, including resource extraction and upgrading, fuel production and distribution processes and vehicle operation and energy demand, which is partly a function of infrastructure, codes and standards and urban planning practices, as well as export and import in fungible commodities that comprise the domestic and international energy markets. LCFS attempts to address these complex and myriad factors through a discrete regulation that relies on a general abstraction that is the lifecycle analysis model of GHG emissions (of which several types exist, but only one is used in Canada: GHGenius). A more efficient and effective approach may be to address each of the critical factors with measures tailored for optimal impact, as laborious as this may appear.

For example, regulation applied at the level of major emitting industrial facilities may be most appropriate for reducing the CI of that portion of the energy supply chain, whereas, financial investments in R&D and in enabling infrastructure might be more appropriate to promote the market uptake of disruptive transportation energy technologies. This approach does not guarantee the achievement of targeted reductions in GHG emissions within a specific timeframe, but it provides for effective management of risk and cost impacts associated with the reductions strategy, and it is potentially more responsive to a range of constraints and opportunities that may change and emerge over time.

Recommendation: The Government of British Columbia should take the lead in developing a national *vision and strategy* on the sustainability of transportation energy use in Canada, for which the provinces, the federal government and industry each have specific responsibilities. BC has demonstrated the will to tackle the complex challenge of transportation and climate change, and this confers a degree of authority and leadership sufficient to convene the key stakeholders in developing an integrated, pan-Canadian suite of measures to reduce GHG emissions throughout the value chain. Ideally, this strategy would align with Canada's national priorities – domestically and internationally – and establish a harmonized structure for change that is multijurisdictional.

A General Recommendation

Regardless of the way forward chosen by the Government of British Columbia, it will require increased capacity through external collaborations, expert input on a wide array of subjects ranging from technology and fuels to economics and policymaking, and advice from individuals and organizations throughout the transportation energy value chain, and from centres of academia. Therefore, Pollution Probe strongly recommends that a special Advisory Group be established, complete with terms of reference and accountabilities, to support the BC government in the execution of its mandate to develop a more sustainable transportation system for the benefit of its citizens. A starting point for this Advisory Group would be to review and debate the recommendations presented in this section, from which a proposed action plan could be developed.

Chapter 8: Conclusion

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Chapter 8: Conclusion

The range of issues and the diversity of opinions reflected in this report, which is itself a mere summary of the information presented, exchanged and discussed at workshop that Pollution Probe held in October 2011 in Victoria, BC, hints at the complexity of the process of transforming the transportation energy value chain, and the uncertainties that constrain action. Yet, this is precisely the change that RLCFRR aspires to bring about. Pollution Probe believes that such transformation requires interventions that go beyond the scope of traditional tools of regulation. It is appropriate for government to lead, but the actions will require a new, collaborative approach involving experts, private sector organizations and, importantly, an engaged and responsive public.

With the publication of this report, Pollution Probe delivers on the intended outcomes of this initiative:[12]

1. information and knowledge exchange among key international stakeholders regarding the implications of LCFS-based regulations;
2. identification of LCFS-based policy options and alternatives; and
3. a synthesis report, including recommendations for future actions, specifically in the BC context.

This work would not have been possible without the support and engagement of the organizations and individuals who advised us throughout the development of the workshop agenda (see the Acknowledgements section), who travelled from afar to Victoria, BC, to participate in the workshop (see Appendix B – Workshop Participants), to the reviewers of the preliminary drafts of this report and to Delphi Group, who assisted in all aspects of the project. To these friends and colleagues of Pollution Probe, we direct our sincere thanks, and we look forward to continuing the enlightening dialogue that we convened one glorious day on the Pacific Coast in October 2011.

12 Specific workshop objectives, which lead to the intended outcomes, are listed in the Introduction.

Appendices A & B

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The Workshop on Low Carbon Fuel Standards

Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia

October 12-13, 2011

Delta Victoria Ocean Pointe Resort and Spa
Victoria, British Columbia

Appendix A- Workshop Agenda

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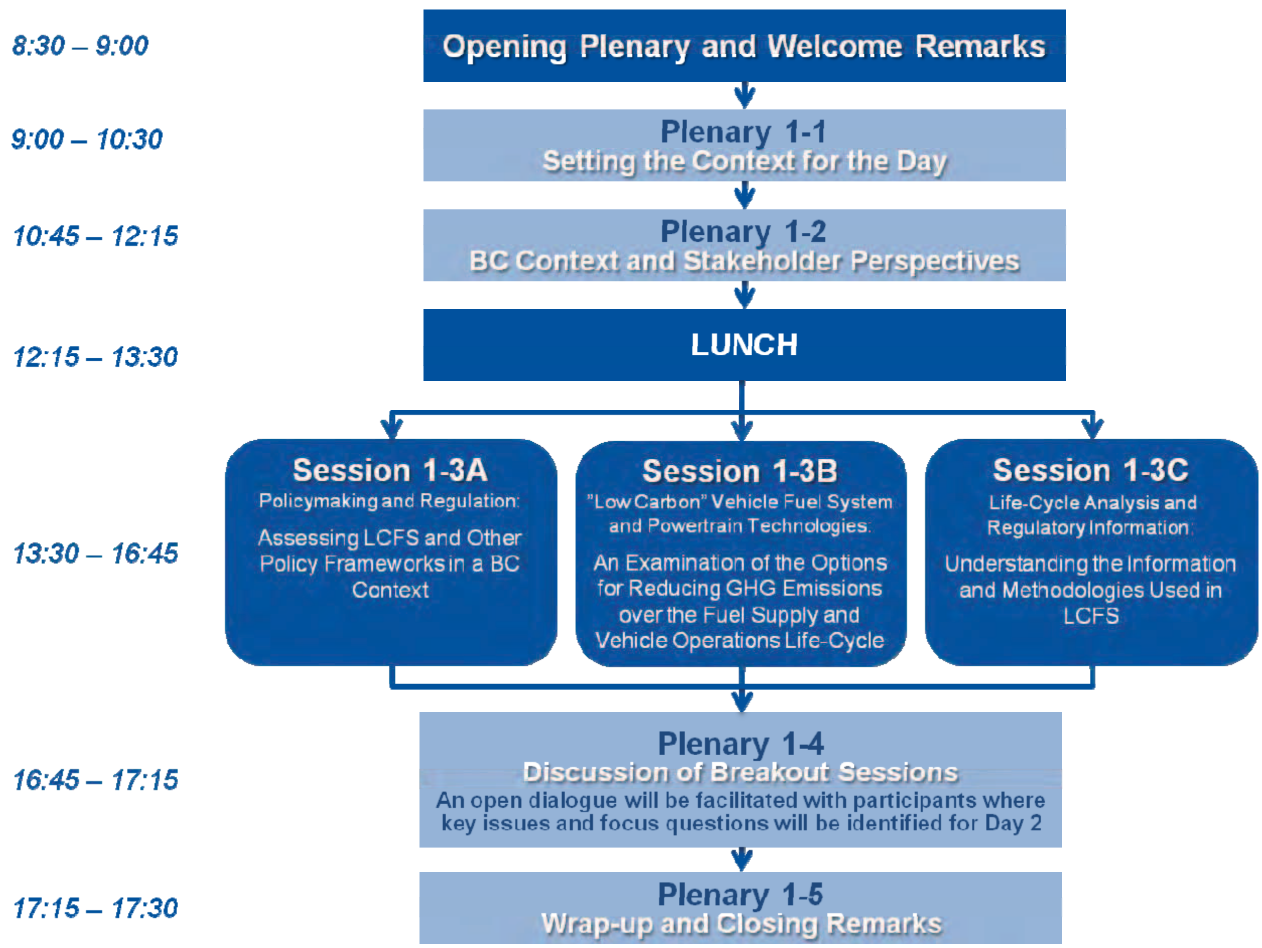
The Workshop on Low Carbon Fuel Standards

Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia

AGENDA FLOW DIAGRAM – DAY 1



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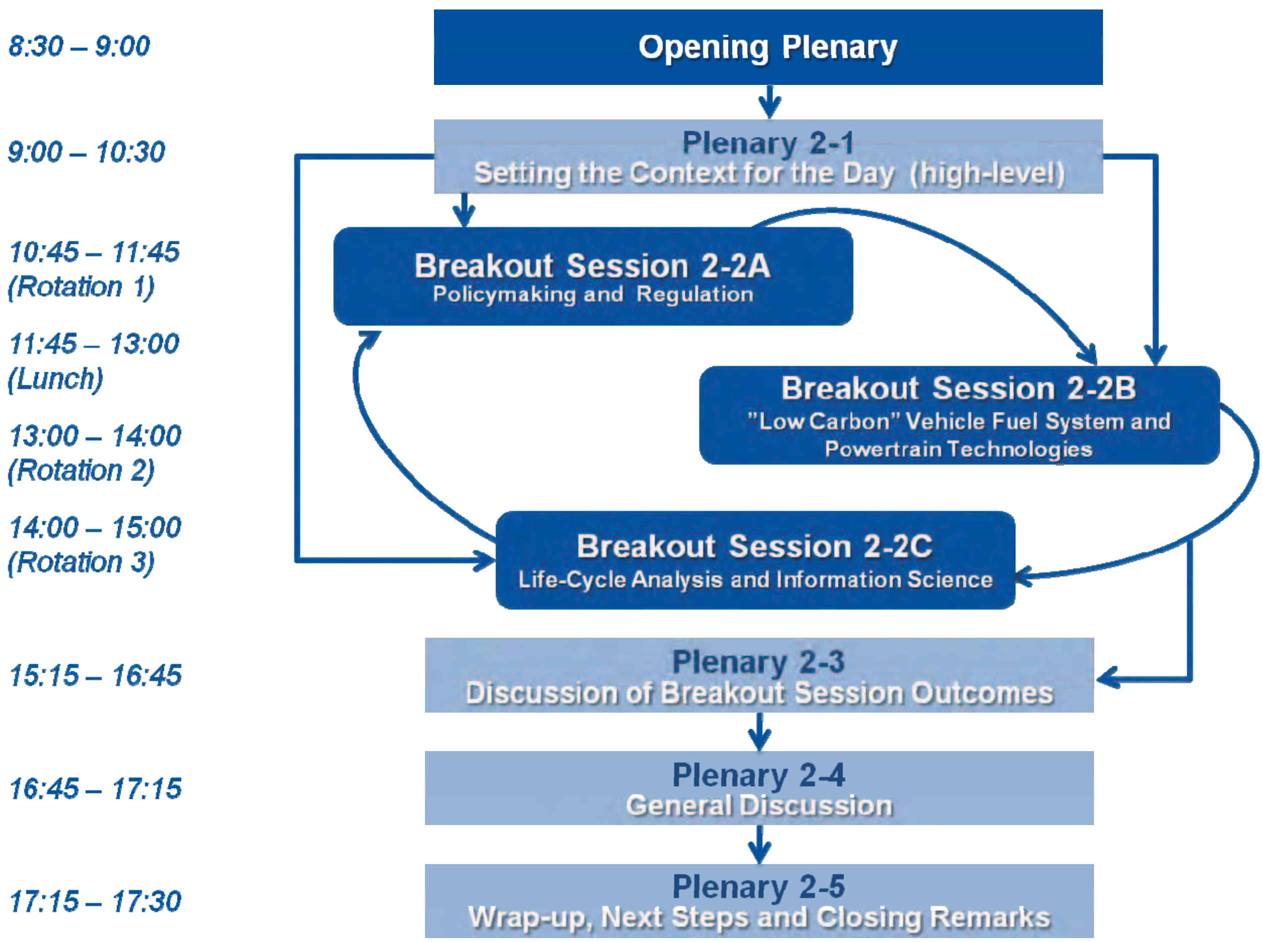
The Workshop on Low Carbon Fuel Standards

Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia

Agenda Flow Diagram – Day 2



The Workshop on Low-Carbon Fuel Standards

Taking Stock of the Implications and Assessing the Future of LCFS in British Columbia

DAY 1

7:00 am – 8:30 am	**Registration and Breakfast *(Foyer)***
8:30 am – 9:00 am **Ascot/Balfour**	**Welcome and Opening Remarks** **Opening Key Note Address, the Honourable Minister of Energy and Mines, Rich Coleman (*Invited*)**
9:00 am – 10:30 am **Ascot/Balfour**	**PLENARY 1-1: Setting the Context for the Day** This session progresses through three presentations, starting from a global perspective on transportation policies in the context of climate change, and bridging to the existing low-carbon fuel requirement in BC. A retrospective of the development of LCFS, led by the State of California, will also be conducted. This will set the context for the conference dialogue. • Dr. Anil Baral, The International Council on Clean Transportation • John Courtis, Manager, California Air Resources Board (*Invited)* • Paul Wieringa, Executive Director, Alternative Energy Branch, BC Ministry of Energy and Mines
10:30 am – 10:45 am	**Refreshment Break *(Foyer)***
10:45 am – 12:15 pm **Ascot/Balfour**	**PLENARY 1-2: BC Context and Stakeholder Perspectives** This session provides an opportunity for fuel suppliers under LCFS to present their perspectives on feasible compliance pathways, and to reflect on the prior presentations from policymakers and regulators. This session will be composed of presentations from stakeholders covering BC, as well as other jurisdictions. ***MODERATOR:*** Len Coad, Director Energy, Environment & Technology Policy, The Conference Board of Canada • Ted Stoner, Vice President, Western Region, Canadian Petroleum Products Institute • Robert Cash, Manager, Environmental, Archer Daniels Midland Canada • Bruce Agnew, Director, Cascadia Center for Regional Development
12:15 pm – 1:30 pm	**Lunch *(Foyer)***
1:30 pm – 4:45 pm	**BREAK OUT SESSIONS 1-3:**
Ascot/Balfour	**SESSION 1-3 A: Policymaking and Regulation – Assessing LCFS and Other Policy Frameworks in a BC Context** Policymakers and regulators need tangible and practical processes to make policy work. This session seeks to build on the topics covered in the opening plenary and address in more detail the question of what policymakers/regulators need to design, implement, monitor and ensure compliance under LCFS, in a practical sense. How does LCFS align with established policy and regulatory assessment criteria? How would LCFS integrate with other GHG regulatory regimes? What alternative, comprehensive frameworks for managing transportation energy use and emissions should be considered? Challenges and opportunities will be explored.
1:30 pm – 3:00 pm	***MODERATOR:*** Monica Arriola, Senior Political and Economic Relations Officer, Consulate General of Canada – San Francisco • Dr. Sonia Yeh, Research Scientist, Institute of Transportation Studies, University of California, Davis • Bill Greenizan, Senior Advisor, Oil, Ontario Ministry of Energy • James P. Uihlein, Fuels Technology Advisor, Chevron

3:15 pm – 4:45 pm	***MODERATOR:*** Robert Redhead, Executive Director, Government Affairs, Newalta Corporation • Gerry Ertel, Regulatory Affairs Manager, Shell Canada • Doug Hooper, Chair of the Government Affairs Committee, Canadian Renewable Fuels Association • Dr. David Stern, Advanced Fuels Senior Advisor, ExxonMobil Refining and Supply Company
Songhees	**SESSION 1-3 B: "Low-Carbon" Vehicle Fuel System and Powertrain Technologies – An Examination of the Options for Reducing GHG Emissions over the Fuel Supply and Vehicle Operations Life-Cycle** Reducing GHG emissions over the entire fuel-vehicle lifecycle has implications for the types of fuel used, as well as for vehicle technology and supporting energy infrastructure. This session will review the range of opportunities-from well to wheels-that are currently available for compliance in BC as well as those that are emerging to reduce transportation GHG emissions using low-carbon fuels and advanced vehicle technologies. A panel of experts will discuss these options and explore the implications of LCFS and other policy frameworks.
1:30 pm – 3:00 pm	***MODERATOR:*** Dr. Craig Fairbridge, Manager Fuels and Emissions, Natural Resources Canada • Ken Mitchell, Fuels Product Quality Excellence Lead, Shell Canada Limited • John German, Program Director, International Council for Clean Transportation • Dr. Sam Shaw, Vice President Natural Gas Policy Development, Encana Corporation
3:15 pm – 4:45 pm	***MODERATOR:*** Ken Ogilvie • Alec Tsang, Senior Technology Strategist, BC Hydro • Christina Ianniciello, Manager of Clean Energy Technologies, British Columbia Ministry of Energy and Mines • Juergen Puetter, President, CEO and Chairman, Blue Fuel Energy Corporation
Chelsea/Derby	**SESSION 1-3 C: Life-Cycle Analysis (LCA) and Regulatory Information: Understanding the Information and Methodologies Used in LCFS** This session seeks to build understanding among conference attendees of the nature of LCA as it relates to transportation energy use and emissions. Panelists will discuss issues, such as data availability, focusing on pragmatic applications of LCA in the implementation of LCFS in BC and elsewhere. The panel will address the potential gaps in data, modeling and science at it relates to LCFS development, as well as other boundary aspects of LCFS, such as the degree of inclusion of upstream emissions, accounting for regulations in other jurisdictions and quantifying direct and indirect land use change and environmental impacts.
1:30 pm – 3:00 pm	***MODERATOR:*** Barry Bower, Barry Bower Consulting • Don O'Connor, President, (S&T) Squared Consultants Inc. • Catherine Reheis-Boyd, President, Western States Petroleum Association • Dr. Anil Baral, The International Council on Clean Transportation
3:15 pm – 4:45 pm	***MODERATOR:*** Dennis Rogoza, President, Rogoza Consulting Group Inc. • Dr. Adam R. Brandt, Acting Assistant Professor, Department of Energy Resources Engineering, Stanford University • Dr. Joule Bergerson, Assistant Professor, University of Calgary • Christopher Holly, Branch Head, Research and Technology, Alberta Ministry of Energy
4:45 pm – 5:15 pm **Ascot/Balfour**	**PLENARY 1-4: Group Discussion**
5:15 pm – 5:30 pm **Ascot/Balfour**	**PLENARY 1-5: Wrap Up and Closing Remarks**
6:00 pm – 8:00 pm	**Reception (*Canoe Brew Pub and Restaurant*)** – See back page of agenda for a map to the venue.

DAY 2

7:00 am – 8:30 am	**Breakfast *(Foyer)***
8:30 am – 9:00 am **Ascot/Balfour**	**Opening Plenary** The key points from the previous day (and evening reception) will be re-iterated and then the objectives and format for the day will be reviewed.
9:00 am – 10:30 am **Ascot/Balfour**	**PLENARY 2-1: Setting the Context for the Day** The workshop facilitation team will outline the process for engaging participants in productive dialogue on how to address the key issues that emerged from the discussion on Day 1.
10:30 am – 10:45 am	**Refreshment Break *(Foyer)***
10:45 am – 11:45 am **Ascot / Balfour** **Songhees** **Chelsea/Derby**	**BREAKOUT SESSIONS 2-2 – Rotation 1** Group A: Policy Making and Regulation Group B: “Low-Carbon” Vehicle Fuel System and Powertrain Technologies Group C: Lifecycle Analysis & Regulatory Information
11:45 am – 1:00 pm	**Lunch *(Foyer)***
1:00 pm – 2:00 pm **Songhees Chelsea/ Derby** **Ascot /Balfour**	**BREAKOUT SESSIONS 2-2 – Rotation 2** Group A: “Low-Carbon” Vehicle Fuel System and Powertrain Technologies Group B: Lifecycle Analysis & Regulatory Information Group C: Policy Making and Regulation
2:00 pm – 3:00 pm **Chelsea/Derby** **Ascot / Balfour** **Songhees**	**BREAKOUT SESSIONS 2-2 – Rotation 3** Group A: Lifecycle Analysis & Regulatory Information Group B: Policy Making and Regulation Group C: “Low-Carbon” Vehicle Fuel System and Powertrain Technologies
3:00 pm – 3:15 pm	**Refreshment Break *(Foyer)***
3:15 pm – 4:45 pm **Ascot / Balfour**	**PLENARY 2-3: Discussion of Breakout Session Outcomes**
4:45 pm – 5:15 pm **Ascot / Balfour**	**PLENARY 2-4: General Discussion**
5:15 pm – 5:30 pm **Ascot / Balfour**	**PLENARY 2-5: Wrap-up, Next Steps and Closing Remarks**

Appendix B – Workshop Participant List

NAME	TITLE	ORGANIZATION
David C. Adams	President	Association of International Automobile Manufacturers of Canada
Bruce Agnew	Director	Cascadia Centre for Regional Development
Brian Ahearn	Senior Regulatory and Planning Advisor	Imperial Oil Limited
Monica Arriola	Senior Political and Economic Relations Officer	Consulate General of Canada, San Francisco
Alison Bailie	Public Sector Services	The Pembina Institute
Dr. Anil Baral	Senior Researcher	The International Council on Clean Transportation
Jacques Bellavance	Manager - Industry and Government Affairs	Shell Canada Products
Dr. Joule Bergerson	Assistant Professor	University of Calgary
Lisa Boulton	Fuel and Quality Compliance Specialist	Husky Energy
Barry Bower	Consultant	Barry Bower Consulting
Adam Brandt	Acting Assistant Professor	Department of Energy Resources Engineering, Stanford University
Dr. Ron Britton	Chief Technology Officer	Blue Fuel Energy Corporation
Tyler Bryant	Energy Policy Analyst	David Suzuki Foundation
Robert Cash	Environmental Manager	Archer Daniels Mildland Canada
Mike Cassaday	Director, Fuel Quality & Regulatory Affairs	Suncor Energy
Nicolas Choquette-Levy	Master's Student, Chemical Engineering (Energy and Environmental Systems)	Institute for Sustainable Energy, Environment and Economy – University of Calgary
Cindy Christopher	Manager, Environmental Policy and Planning	Imperial Oil Limited
Len Coad	Director Energy, Environment & Technology Policy	The Conference Board of Canada
Robert Cooper	Supply Projects	Shell Canada

John Courtis	Manager	California Air Resource Board
Thomas Crist	Policy Analyst	Natural Resources Canada
Jennifer Curran	Manager, Compliance	Parkland Fuel Corporation
Bruce Dudley	Senior Vice President	The Delphi Group
Jenna Dunlop	Manager, Climate Change Policy	Canadian Association of Petroleum Producers
Todd Ellis	VP Business Development	Imperium Renewables
Gerry Ertel	Regulatory Affairs	Shell Canada
Dr. Craig Fairbridge	Manager Fuels and Emissions	Natural Resources Canada
Jean-François Gagné	Senior Manager, Advanced Transportation Fuels	Natural Resources Canada CanmetENERGY
John German	Senior Fellow and Program Director	International Council for Clean Transportation
Fred Ghatala	Secretariat, Climate Change & Sustainability	Canadian Renewable Fuels Association
Patricia Gordon	Director Cities Network	Sustainable Cities International
Paul Gray	Manager, Chevron Burnaby Refinery Supply & Distribution	Chevron Canada Limited
Bill Greenizan	Senior Advisor, Oil	Ontario Ministry of Energy
Robert Hamaliuk	Climate Change Specialist	Alberta Environment
Ron Harmer	Consultant	HRH Consulting
John Heida	Consultant	Purvin & Gertz
Benjamin Herlinger	Sustainable Transportation Engineer	BC Transit Corporation
Christopher J. Holly	Branch Head, Research and Technology Branch, Energy Policy and Research Division	Alberta Department of Energy
Doug Hooper	Chair, Government Affairs Committee	Canadian Renewable Fuel Association
Christina Ianniciello	Manager, Communities and Transportation	BC Ministry of Energy and Mines

Appendix B – Workshop Participant List

Fiona Jones	Director, Energy and Climate Change Policy	Suncor Energy
Michael Kandravy	Senior Advisor, Regulatory Affairs	Suncor Energy
Marie-Helene Labrie	Vice President, Government Affairs and Communications	Enerkem
Jenny Luu	Policy Analyst	Transport Canada
Husam Mansour	Chief Operating Officer	Pollution Probe
Robert McKinstry	Director, Policy, Economic & Environmental Affairs	Railway Association of Canada
Andrea Mercer	Transportation Emissions Policy Specialist	Climate Action Secretariat, BC Ministry of Environment
Alicia Milner	President	Canadian Natural Gas Vehicle Alliance
Ken Mitchell	Fuels Engineer	Shell Canada
Gilles Morel	Director – Fuels	Canadian Petroleum Products Institute
Isolde Mudie	Senior Project Coordinator	Geoscience and Strategic Initiatives Branch, BC Government
Anamika Mukherjee	Advisor, Environment Policy & Strategy	Cenovus
Don O'Connor	President	S&T Squared Consultants
Ken Ogilvie	Vice-Chair	Quality Urban Energy Systems of Tomorrow
Bob Oliver	Chief Executive Officer	Pollution Probe
Dennis Paradine	Manager, Climate Change Policy	B.C. Ministry of Environment, Climate Action Secretariat
Juergen Puetter	President	Blue Fuel Energy Corporation
Dar Purewall	Social Mobilization Analyst	Climate Action Secretariat, BC Ministry of Environment
Bob Redhead	Executive Director Government Affairs	Newalta Corporation
John Reese	Advocacy Excellence Manager, NA	Shell Oil Products US
Catherine Reheis-Boyd	President	Western States Petroleum Association

Michael Rensing	Manager, Renewable and Low Carbon Fuels Renewable Energy Development Branch	BC Ministry of Energy and Mines
Mark Rizzo	District Sales Manager	Chevron Canada Limited
Wishart Robson	Climate Change Advisor to the President and CEO	Nexen
Dennis Rogoza	President	Rogoza Consulting Group
Heli Salmenpohja	Marketing Manager	Neste Oil Corporation
Dave Schick	Climate Regulation Specialist	Chevron Canada Limited
Sam Shaw	Vice President, Natural Gas P olicy Development	Encana Corporation
Paul Shorthouse	Director of Special Project & GLOBE Series Conference Program Manager	Globe Foundation
Roger Smith	Executive Director	Fleet Challenge Ontario
James Sobota	Project Manager	Pollution Probe
Nicole Spears	Section Head, International/ National Policy, Climate Change Secretariat and Clean Energy	Alberta Environment
David Stern	Advanced Fuels Senior Advisor	ExxonMobil Refining and Supply Co.
Cameron Stonestreet	Business Development Associate	Pacific Carbon Trust
Ted Stoner	Vice President Western Division	Canadian Petroleum Products Institute
Yasmin Tarmohamed	Vice-President, Environment, Health and Safety	Canadian Vehicle Manufacturer's Association
Ian Thomson	Chair, Climate Change & Sustainability Committee	Canadian Renewable Fuels Association
Annette Tobin	Senior Policy Advisor	Oil Sands and Energy Security, Natural Resources Canada
Alec Tsang	Senior Technology Strategist	BC Hydro
Jim Uihlein	Advisor, Fuels Technology	Chevron Canada Limited
Evelyn Walker	Vice President	The Delphi Group
Paul Wieringa	Executive Director, Alternative Energy Policy Branch	BC Ministry of Energy and Mines

Irene Wingfield	Administration and Mapping Assistant	Ministry of Energy and Mines
Peter Wynne	Technical Specialist	Chevron Canada Limited
John Yap	Parliamentary Secretary	BC Ministry of Energy and Mines
Sonia Yeh	Research Scientist, Institute of Transportation Studies	University of California

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